Socioenvironmental Factors in Fall-Related Injury: A Hospital Registry Study

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ABSTRACT

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Accidental falls remain a significant public health problem as injury rates are increasing despite aggressive prevention efforts. This study hypothesized that prevention programs are ineffective due to a generic focus on the elderly, and an unrecognition of place-related effects involved in the etiology of injurious falls. A social epidemiological framework to fall-related injury assessment was applied as it would address socioenvironmental factors lacking in traditional patient-centered models. Utilizing a state-wide hospital registry, a retrospective, ecological population-based cohort study was conducted to explore how fall-related injuries vary based on the level of urbanization and socioeconomic deprivation. Study objectives were to estimate the incidence of fall-related injury by age, gender, and geographic unit for an entire state over five years, and to assess place-related effects. Descriptive statistical results were similar to those nationally reported, with injury rates highest in younger and older populations. Multivariate regression demonstrated that population size and density had a curvilinear relationship with fall injury, with injury rates higher in less populated towns. Moreover, socioeconomic deprivation had a strongly positive association with fall injury. The combined net effect of its interaction with age, gender, and population size showed a significant increase in injury rates among young males, as well as young and middle-aged adults residing in towns with high socioeconomic deprivation. Conventional risk factors associated with

physical development and aging may be stronger determinates for fall-related injury in the youngest and oldest populations whereas socioenvironmental factors may increase injury risks in younger and middle-aged adults through different mechanisms.

Socioenvironmental Factors in Fall-Related Injury: A Hospital Registry Study

CHAPTER 1: INTRODUCTION

1.1 Background

Despite aggressive prevention efforts, falls remain a significant public health problem within the United States (U.S.). They are a primary source of injury-related emergency department (ED) visits and a leading cause of hospital admissions for persons of all ages (Bergen, Chen, Warner & Fingerhut, 2007; Borse et al., 2008; Murphy, Xu, & Kochanek, 2014; Villaveces, Mutter, Owens & Barrett, 2013). To date, research on the epidemiology of fall-related injury has concentrated efforts on the elderly and setting as it relates to the immediate built environment (Gillespie et al., 2012; Sleet, Moffett, & Stevens, 2008). Consequently, fall prevention programs maintain a general focus on older adults across a variety of environments. Prevention efforts may miss the mark in effectiveness because they fail to consider the "social" and "geographic" factors involved in the etiology of injurious falls across all ages. Therefore, this study directs attention on how fall-related injury may vary from rural to urban environments and inquires as to whether there is significant variation related to residential populations with high levels of socioeconomic deprivation (SED).

Falling is a mechanism of injury, one which presents an immense public health burden as its impact extends beyond the individual to families, communities, and healthcare systems. Consequences associated with fall-related injury can lead to premature death, long-term disability, psychological trauma, and increased healthcare costs (Bergen et al., 2007; Centers for Disease Control and Injury Prevention, 2014;

Injury Surveillance Workgroup on Falls, 2006; Murphy et al., 2014; U.S. Department of Health and Human Services, 2013). Published data by Verma et al., (2016) exemplifies the magnitude of this national health issue as the total lifetime costs of annual fall-related injuries among adults exceeded 110 billion dollars in 2010. Also, unlike all-cause injuries, nearly all fall-related injuries are attributed to unintentional or accidental circumstances, with most falls considered to be preventable in spite of their accidental nature (Injury Surveillance Workgroup on Falls, 2006).

Persons of all ages are at risk for fall-related injuries. However; reported injury rates are consistently higher in the youngest and oldest age cohorts (Injury Surveillance Workgroup on Falls, 2006). Such activity is reflected in data demonstrating that fall-related injuries are the primary source of non-fatal injuries in children aged 1-19 years and the number-one cause of death in those 65 years and older (Borse et al., 2008; Centers for Disease Control and Injury Prevention, 2014). When implementing targeted fall prevention programs, it is essential to recognize the differences in fall mechanisms and related injury patterns by age (Injury Surveillance Workgroup on Falls, 2006).

Circumstances or conditions leading to fall-related injuries can often influence the extent of physical trauma incurred; such as the height from which the fall took place, or the type of surface involved in the fall event (Injury Surveillance Workgroup on Falls, 2006). Also, various factors can increase risks for injury. Fall risk factors are commonly categorized as being either intrinsic or extrinsic in nature (Bueno-Cavanillas, Padilla-Ruiz, Jimenez-Molen, Peinado-Alonso, & Galvez-Vargas, 2000; Currrie, 2006; Injury Surveillance Workgroup on Falls, 2006; Feldman & Chaudhury, 2008). Intrinsic factors are physiologically oriented, for example, relating to age, functional status, and overall health condition. Extrinsic factors are environmentally situated, for instance, consideration to walking surface areas, home hazards, and other place-related precipitating exposures.

Fall-related studies largely focus on intrinsic fall risks in older populations and extrinsic causes of falls in younger age cohorts, substantiating the differentiation in injury patterns across the life course (Gillespie et al., 2012; Injury Surveillance Workgroup on Falls, 2006; Sleet et al., 2008). While fall risks in older adults are often physiologically-based, the impact of extrinsic factors, such as home hazards, footwear, and walkways, is noteworthy (Centers for Disease Control and Injury Prevention, 2013). Additionally, the attention to fall risks in children and younger adult populations has centered on environmental factors associated with home, recreational, and work settings (Borse et al., 2008; National Institutes for Occupational Safety and Health, 2004; Pomerantz, Gittelman, Hornung & Husseinzadeh, 2012).

Lacking in current falls research is an expanded context of extrinsic causes, one that accounts for the social and geographic factors involved in the etiology of injurious falls (Injury Surveillance Workgroup on Falls, 2006; Sleet et al., 2008). The World Health Organization (WHO; World Health Organization, 2009) recognizes that while the numbers of studies which address socioeconomic status (SES) and injury risk have grown over the last two decades; few have focused on fall risks, and completed studies demonstrate mixed findings in both pediatric and adult populations. Studies that have examined the relationship of urban-rural variation and injury rates have established differences with both intentional and unintentional injury mechanisms (Boland, Staines, Fitzpatrick & Scallan, 2005; Leff, Stallones, Keffe, Rosenblatt, & Reeds, 2003).

This study theorized that socioeconomic determinants, specifically urbanization and SED, assume a more influential role in a community's overall fall-related risks. For example, older inner-city row homes in economically depressed areas can expose the young and old to an increased risk of falling due to their multiple-story structure, narrow stairways, and general structural disrepair. Also of consideration are disparate levels of public amenities or community infrastructures, such as pedestrian walkways and transportation services, which can significantly impact residents' risks for injurious falls. Furthermore, conventional fall prevention programs that encourage daily exercise may present unique challenges for populations living in communities that lack venues or safe access to venues for such activity.

1.2 Purpose and Specific Aims

The purpose of this epidemiological study was to explore the impact of place effects and social environments on fall-related injuries. More explicitly, the research question asked if fall-related injuries across various age and gender cohorts differed for urban versus rural environments and if there was a disparity in certain residential populations related to high levels of socioeconomic deprivation. Therefore, the central hypothesis of this study was that fall-related injuries exhibited in defined age and gender cohorts differ based on levels of population size, population density, and socioeconomic deprivation.

The specific aims of this study were to:

1. Evaluate a state-wide hospitalization registry to estimate the age-specific incidence of subacute and acute fall-related injury by gender for the entire state of New Jersey for the period 2009 through 2013, with detailed analysis of 2010 data focusing on emergency department visits and number of hospital stays, in comparison with the population at risk as enumerated in the 2010 decennial census.
2. Estimate the age-specific incidence of subacute and acute fall-related injury requiring emergency department treatment or hospitalization, by gender for the 566 county civil divisions in the state of New Jersey for the period 2009-through 2013.
3. Test for confounding and effect modification of subacute and acute fall-related injury by county civil division population size, population density, as well as SED.
4. Discuss the implications of the social epidemiology of fall-related injury for the development of community-based fall prevention programs.

1.3 Significance

With persons of all ages exposed to fall risks in diverse locations, an enhanced understanding of discrete population characteristics and environmental settings which significantly influence the risk of serious injury remains critical to the development of effective prevention strategies (Bergen et al., 2007; Injury Surveillance Workgroup on Falls, 2006). Additionally, given the preponderance of fall-related research and prevention efforts skewed towards older adults and the immediate built environment, the CDC established research priorities to address current gaps in population disparity associated with age, gender, ethnicity, and socioeconomic status (Injury Surveillance Workgroup on Falls, 2006; Sleet et al., 2008). This study responded to these research priorities by examining the variation of fall-related injury in relation to urbanization and SED across all ages.

Fall-related injury significantly impacts the nation's public health. The U. S. Department of Health and Human Services has recognized fall prevention as a priority for Healthy People 2020, a long-term initiative designed to promote health, decrease injury, reduce disparities, and improve the quality of life for all persons (U.S. Department of Health and Human Services, 2013). Working from the framework set forth by Healthy People 2020, various public and private entities are called upon to develop, implement, and support health promotion and injury prevention initiatives. For organizations to be effective in injury mitigation efforts, they have an obligation to understand their target population demographics, including disease and injury patterns. By utilizing various state-wide databases and other pooled sources of data related to injury, information required making appropriate decisions related to injury-specific health policy, programs, and funding will be accessible. This study applied two such lines of evidence, a state-wide hospital registry and the decennial census to examine fall-related injuries within the state of New Jersey.

Located in the Mid-Atlantic region of the United States, New Jersey is boarded by the states of New York, Pennsylvania, and Delaware, as well as the Atlantic Ocean. With

8.8 million residents, New Jersey is not only the 11th most populous state; it is also one of the most densely populated states (World Population Statistics, 2013). Additionally, New Jersey has the third highest per capita personal income in the nation (U.S. Department of Commerce, 2013). That said there is considerable disparity in the level of population size, density, and socioeconomic status among New Jersey's 566 county civil divisions (CCD; State of New Jersey Department of Health, n.d.).

Given New Jersey's widely variable communities, study objectives not only centered on determining the age-specific incidence of injury associated with falls, but also determining the impact that divergent population size, density, and SED have on fall injury rates. It is suggested that the establishment of a state-specific epidemiologic profile, or fall-related injury signature, would provide meaningful guidance for the development of population-targeted fall prevention programs.

1.4 Conceptual Framework

This study utilized a social epidemiological framework. As levels of urbanization and SED were investigated with respect to fall-related injury, a social epidemiological context was considered fitting as tenets of this discipline center on the social distribution and social determinates of disease or injury (Berkman & Kawachi, 2000b). Additionally, the principles of a social epidemiological framework are grounded in psychosocial approaches as well as the social production of disease/political economy of health and the eco-social environment.

While social epidemiology may be considered a relatively new science, the belief that social conditions influence health is not new. Born in 450 BC, Hippocrates, one of the most outstanding figures in the history of medicine, was the first to identify social and environmental influences on disease (Bonita, Beaglehole, & Kjellström, 2006). Guided by ideologies and scientific methodologies originating from the Period of Enlightenment, numerous scientists during the 19th century published investigational accounts which associated social conditions, social position, and resource access to the distribution of disease and disparities in mortality (Chadwick, 1842; Durkheim, 1897/1951; Villerme, 1988; Virchow, 1988).

During the 19th and early parts of the 20th centuries, virulent diseases such as cholera, anthrax, and smallpox significantly impacted health outcomes of large populations. Investigations by distinguished scientists, for instance, Snow, Koch, and Pasture, dispelled the pervasive belief in spontaneous generation of disease and propagated new theories of causation, most notably germ theory and the triangle of causation. As a result, previous attention given to social influences on disease distribution shifted to single individual risk factors. Subsequent ideologies brought forth a biological paradigm that reinforced traditional medical and epidemiological approaches to disease (Pearce, 1996; Susser & Susser, 1996).

In the biological model of disease distribution, all conditions are considered to be biologic phenomena and therefore thought of exclusively in biologic terms (Engel, 1977; Honjo, 2004; Krieger, 1994). Such drives a viewpoint in which a population is the aggregate of its individuals, and the distribution of disease is a compilation of individual risk factors. Of most consequence, this biological or mainstream model does not acknowledge social level factors in the causal pathway of disease (Honjo, 2004; Krieger, 1994).

Theories associated with multiple-causation began emerging during the middle and the latter half of the 20th century as drivers of population mortality shifted from infectious to non-infectious causes (Honjo, 2004; Krieger, 2001). Epidemiologist and sociologist refocused their attention on the relevance of social conditions and the distribution of disease, and more importantly, on the idea that exposure to multiple individual and societal risk factors causes disease. Furthermore, the proliferation of studies demonstrating the impact of low socioeconomic status on morbidity and mortality rates associated with non-infectious conditions impacted this change in mindset concerning disease causality (Antonovsky, 1967; Cassel, 1976; Kitagawa & Hauser, 1973; Marmot, Shipley & Rose, 1978; Syme, Hyman & Enterline, 1964).

The term "social epidemiology" first appeared in the title of an article published in 1950. S. Leonard Syme, considered to be the father of social epidemiology, authored numerous publications that emphasized the influence that social determinants had on health and well-being. These determinants included; socioeconomic status, quality of the socio-environment, race and ethnicity, social support and connection, as well as environmental stress (Syme, 1971; Syme & Balfour, 1999; Syme & Berkman, 1976). Additional research studies of this time linked various social conditions to an array of health issues, most notably chronic diseases (Link & Phelm, 1995; Marmot et al., 1991: Syme & Berkman, 1976). Collectively, these studies disputed the dominant biomedical model and championed an alternative paradigm that underscored the influence of social determinates and distribution of disease. Figure 1 provides an overview of the traditional biomedical/lifestyle versus social epidemiologic theories of disease distribution.

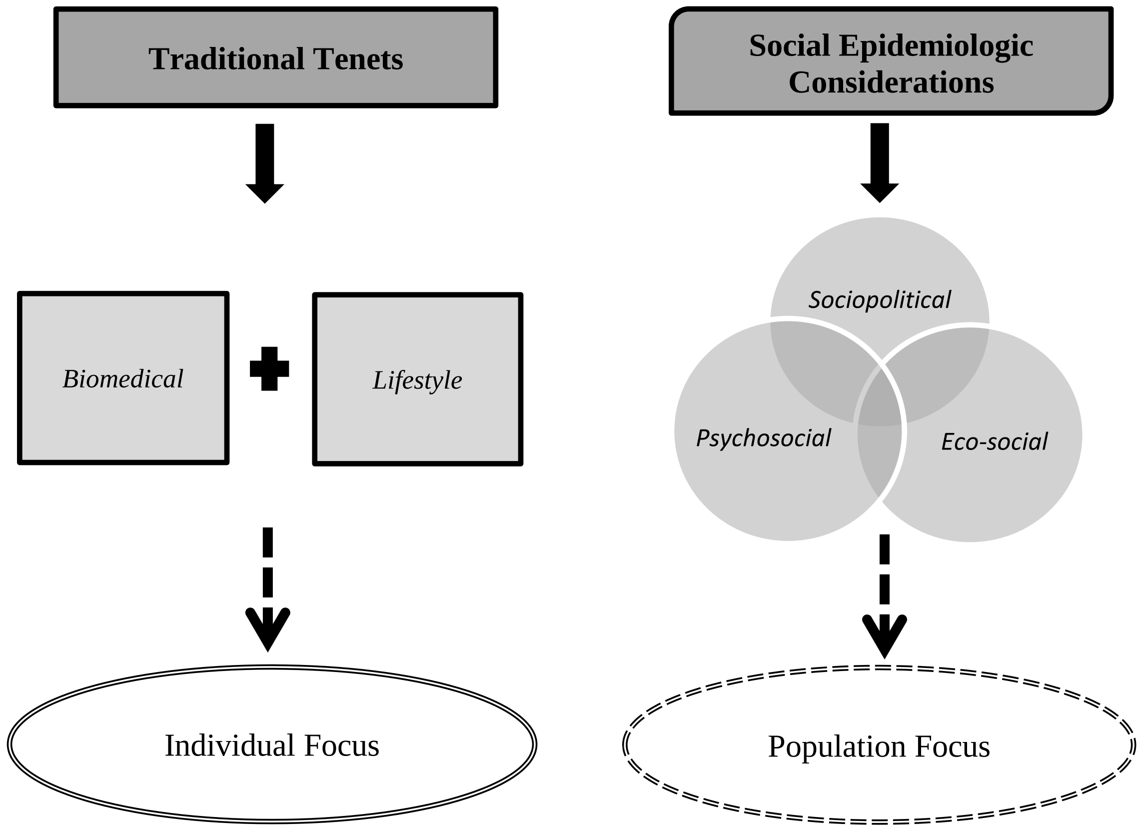

Figure 1: Traditional Tenets of Disease Distribution as Compared to Social Epidemiologic Considerations.
Adapted from "Epidemiology and The People's Health," by N. Krieger, Oxford University Press, 2011, p. 164. Copyright 2011 by the Oxford University Press.

Krieger (2011) identifies three distinct theoretical tenets considered foundational to contemporary social epidemiology. The first of these perspectives, sociopolitical theory, is concerned with power, politics, economics, and rights as fundamental determinants of population health (Krieger, 2011, p.163). The second viewpoint, psychosocial theory, places emphasis on the psychologically- mediated determinants of health (Krieger, 2011, p.163). Lastly, and building on the other two theories, eco-social theory considers the social, ecological, and historical contexts of disease distribution (Krieger, 2011, p.163). While all three theoretical frameworks are distinct, they have certain overlapping features. Fundamental to all three theories is the belief that the distribution of health and disease cannot be understood apart from their societal context. Also, that socially patterned processes determine health and disease outcomes and that as society changes, population levels and distribution of health and illness will change (Krieger, 2011, p.163).

It was proposed that the application of a social epidemiological framework to fall-related injury assessment will address social and environmental factors that are currently lacking in biomedical physiological patient-centered models (Injury Surveillance Workgroup on Falls, 2006; Sleet et al., 2008; World Health Organization, 2009). Using a social epidemiologic framework to falls research linked to evidence which demonstrates "place-related" risk factors provides further justification for its application. Specifically, that the neighborhood built and social environment are associated with excess morbidity and mortality (Cuban, LeClere & Smith, 2000; Williams, Currie, Wright, Elton & Beattie, 1996; World Health Organization 2009). Also, differential susceptibility to falls related to SED raises health disparity issues inadequately addressed in current fall prevention programs (Injury Surveillance Workgroup on Falls, 2006; Sleet et al., 2008; World Health Organization, 2009).

1.5 Summary

Falls remain a significant public health problem in the U.S. as they are the leading cause of injury resulting in emergency department visits and hospital admissions across all ages (Bergen et al., 2007; Borse et al., 2008; Murphy et al., 2014). Fall-related injury and its associated consequences reach beyond the individual, as families, communities, and healthcare systems are significantly impacted. Premature death, long-term disability, loss of social productivity, and increased healthcare costs collectively contribute to this public burden (Bergen et al., 2007; Centers for Disease Control and Injury Prevention, 2014; Injury Surveillance Workgroup on Falls, 2006; Murphy et al., 2014; U.S. Department of Health and Human Services, 2013; Verma et al., 2016).

Current research on the epidemiology of fall-related injury has primarily focused on the elderly and immediate built environment (Gillespie et al., 2012; Sleet, Moffett, & Stevens, 2008). Subsequently, fall prevention programs have maintained a generic focus on older adults across widely diverse environments. Such an approach to injury prevention programs may be ineffective as they fail to take into account the "social" and "geographic" influences involved in the etiology of injurious falls across all ages.

As persons of all ages in diverse settings remain vulnerable to falls, a better understanding of discrete population and environmental characteristics which increase risks for fall-related injury is crucial to the development of effective prevention strategies (Bergen et al., 2007; Injury Surveillance Workgroup on Falls, 2006). The intent of this epidemiological study was to address specific gaps in the falls literature by examining the variation of fall-related injury in relation to urbanization and SED across all ages. Given the variable nature of towns or communities within in New Jersey, study objectives focused on establishing the age-specific incidence of injury associated with falls as well as estimating the effect of different population size, density, and SED on fall injury rates. Also, it was postulated that the establishment of a state-specific epidemiologic profile of fall-related injury would provide the foundation for population-targeted fall prevention programs. Lastly, the application of a social epidemiological framework to fall-related injury assessment would address social and environmental factors currently lacking in biomedical physiological patient-centered models of disease and injury (Injury Surveillance Workgroup on Falls, 2006; Sleet et al., 2008; World Health Organization, 2009).

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

A review of the falls literature revealed an extensive body of works. However, it further validated that the majority of fall-related research has centered on issues germane to older adults and the immediate built environment. Few studies have adequately addressed the relevance of socioenvironmental factors involved in the etiology of injurious falls (Bohannon, Hanlon, Landerman, & Gold, 1999; Grisso, Schwarz, Wolfson, Polansky, & laPann; 1992; Hanlon, Landerman, Fillnenbaum, & Studenski, 2002; Heesch, Byles, & Brown, 2008; Stevens & Sogolow, 2005). While there has been a recent increase in the number of studies focused on socioeconomic status (SES) and injury risks, limited attention has been given to specific fall-related injury risks (Boland et al., 2005; Injury Surveillance Workgroup on Falls, 2006; Leff et al., 2003; Sleet et al., 2008; World Health Organization, 2009). Furthermore, of those studies which have looked at SES in relation to fall injury, findings remain mixed (Basta, Matthews, Fiona, Chatfield, & Bray, 2007; Birken & MacArthur, 2004; Hong, Leem Ha, & Park, 2010; Lyons, Jones, & Heaven, 2003; Kamla, Wilson, & Hasselberg, 2014; Siracuse et al., 2012; World Health Organization, 2009; Williams, Currie, Wright, Elton, & Beattie, 1997).

As persons of all ages are at risk for falling and therefore sustaining a fall-related injury, the overarching purpose of this research project was to not only assess variation in fall injury outcomes based on socioeconomic factors, specifically the level of urbanization and SED, but to do so for all ages and genders. Given the broad scope of accidental falls, the literature review addressed the following fall-related injury topics; basic falls definitions, the incidence of fall-related injury, falls in pediatric, adult and elderly populations, fall risk factors with special consideration of race-ethnicity, SES, and urban versus rural geographies, and lastly fall prevention.

2.2 Fall and Fall-Related Injury Definitions

Essential to any exploration of a population health issue is the need to establish operational definitions. The Centers for Disease Control and Injury Prevention (CDC) has set standard definitions for "fall" and "fall-related injury," as well as surveillance guidelines to provide consistency in the approach to national fall-injury monitoring (Table 1).

Table 1: Centers for Disease Control and Injury Prevention Definitions for Fall and Fall-Related Injury

Term	Definition
Fall	An event which results in a person coming to rest on the ground or other lower level precipitated by a misstep such as a slip, trip, or stumble; from loss of grip or balance; from jumping; or from being pushed, bumped, or moved by another person, animal or inanimate object or force.
Fall-Related Injury	An injury precipitated by a fall (as defined above) and caused by striking an injury-producing surface.

Included in the five recommendations provided by the CDC for fall-related injury surveillance, is the use of the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) system. This classification scheme promotes "international comparability in the collection, processing, categorization, and presentation of mortality and morbidity statistics" (Injury Surveillance Workgroup on Falls, 2006, p. 19). There are two sets of ICD-9-CM codes used for identifying injury cases; (1) the Nature of Injury codes used to document bodily harm as well as specific site of injury, and (2) the External Cause of Injury codes used to identify the mechanism of injury (Centers for Disease Control and Injury Prevention, 2009; Injury Surveillance Workgroup on Falls, 2006). Shown in Table 2 are the specific fall-related ICD and mechanism codes.

Table 2: Fall-Specific International Classification Disease Codes

Data Source		Fall Mechanism Codes
International Classification of Diseases (ICD)	ICD- Version 9, ICD-9-Clincial Modification (CM)	E880-E886 E888 E957 E968.1 E987

Despite national and international efforts to standardized definitions and methods for the measuring and reporting of fall-related injuries, there is inconsistency among published studies (Lamb, Jorstad-Stein, Hauer, & Becker, 2005; Schwenk et al., 2012). A current review of the literature conducted by Schwenk et al. (2012) reveals heterogeneity among fall injurious definitions with most fitting into one of three categories; symptom based, healthcare use based, and the combination of symptom and healthcare use. The most frequently used definition is attributed to Campbell et al. (1997), which further applies a sub-classification to falls according to injury severity such as minor, moderate, or severe. This sub-classification incorporates injury features or symptoms, for example, fractures, in addition to healthcare use, such as an emergency department visit or specific medical intervention. Other fall definitions appearing in the literature are based on the Frailty and Injuries Cooperative Studies of Intervention Techniques (FICSIT) collaborative and the Abbreviated Injury Scale (AIS; Hauer, Lamb, Jorstad, Todd, & Becker, 2006; Schwenk et al., 2012).

2.3 Incidence of Fall-Related Injury

Nationally, accidental falls are the leading cause of non-fatal injuries and the third leading cause of fatal injuries (Bergen et al., 2007; Centers for Disease Control and Injury Prevention, 2014; Borse et al., 2008; Verma et al., 2016). Moreover, between 1990-2010, falls ranking increased from the 24th to the 15th leading cause of disability-adjusted life years (DALYs), with more than a 50% increase in DALYs (Institute for Health Metrics and Evaluation, 2010). While persons of all ages incur fall-related injuries the most vulnerable are the youngest and the oldest populations (Injury Surveillance Workgroup on Falls, 2006). The accidental fall rate for children 0-19 years of age is estimated to be 25-35% (Bulut, Korkmaz, Turan, & Ozguc, 2006; Kocak et al., 2012). Annually, falls account for more than 2.8 emergency department visits and more than 10,000 hospital admissions in the pediatric population (Centers DC, 2014; Borse et al., 2008). For senior adults, those 65 years and older, falls are the primary cause of injury-related deaths. One in three or 3.2 million older adults incurs a fall-related injury per year resulting in 2.5 million emergency department visits and over 700,000 hospitalizations (Centers for Disease Control and Injury Prevention, 2013; Verma et al., 2016).

The reported death rate for older adults has substantially risen over the last decade despite aggressive prevention efforts (Bergen et al., 2007; Murphy et al., 2014; Verma et al., 2016; Villaveces et al., 2013). From 2000-2013 the age-adjusted death rate related to falls for adults 65 years and older almost doubled 29.6 per 100,000 to 56.7 per 100,000 (Kramarow, Chen, Hedegarard, & Warner, 2015). Also, the fall death rate for elderly adults 85 years and older is reported to be four times that of those aged 75-84 years, and nearly 16 times higher than those 65-74 years of age (Kramarow et al., 2015). As our population ages the trend in older adult fall-related injury rates will continue rise; therefore, much attention will continue to be given to fall prevention in this population cohort.

2.4 Falls in Pediatric Populations

On a national scale, unintentional falls are among the top causes of fatal injuries in all pediatric age groupings. Also, falls are the primary mechanism of nonfatal injuries for children under 15 years of age, and the second leading mechanism of nonfatal injury in children 16-19 years (Borse et al., 2008). The nonfatal fall-related injury rate for those 0-19years of age is 3,420 per 100,000 (Borse et al., 2008). Males are reported to have a higher nonfatal fall rate at 3,871 per 1000,000 than females, who have a nonfatal fall rate of 2,946 per 100,000 (Borse et al., 2008). Also, pediatric falls are associated with substantial physical, psychosocial, and financial consequences even though they may have a lower mortality as compared with other prominent pediatric injury mechanisms, such as motor vehicle crashes. Of note, within the United States the annual costs of unintentional pediatric injury, of which falls is the leading cause, is estimated to be $300 billion (Borse et al., 2008).

Historical studies related to pediatric falls have centered on types of falls, for example, falls from windows or playground equipment. More contemporary research efforts have examined injury patterns among pediatric age cohorts. Stages of development influence a child's exposure to different falls risks as well as fall-related injury patterns (Flavin, Dostaler, & Simpson, 2006; Tracy et al., 2013; Unni, Locklair, Morrow, & Estrada, 2012). Additionally, though there are standards of pediatric age groupings established by the National Institute of Health and Human Development Conference, there may be underreporting or misclassification of pediatric falls due to variation in applied age criterion (Tracy et al., 2013; Unni et al., 2012).

Extrinsic, or environmental factors, are most commonly associated with pediatric fall injuries. Most infant falls are a result of being dropped by their caretakers, or falls from furniture or countertops when left unattended (Ibrahim, Wood, Margulies, & Christina, 2012; Pomerantz, Gittelmanm, Hornung, & Husseinzadeh, 2012; Unni et al., 2012). Children one through nine years of age sustain injuries falling down stairs as well as falls from furniture, windows, and playground equipment (Pomerantz et al., 2012; Unni et al., 2012). Children 10 through 14 years of age tend to sustain injuries associated with falls from playground equipment, tripping and slipping, and falls from vigorous play

(Borse et al., 2008; Unni et al., 2012). Adolescents, those 14-19 years of age, are more likely to sustain injuries from falls related to sports and recreational activity (Borse et al., 2008; Injury Surveillance Workgroup on Falls, 2006; Unni et al., 2012; Wang, Zhao, Wheeler, Yang, & Xiang, 2013).

Current pediatric falls literature supports the finding that the height and landing surface influence the severity of the injury. Children falling ≥ 10 feet, or two stories or higher, are more at risk for sustaining serious or multiple injuries in addition to having higher mortality rates (Haney, Starling, Heisler, & Okwara, 2010; Harris, Rochette, Smith & Smith, 2014; Lallier, Bouchard, St-Vil, & Tucci, 1999). Severe or acute fall-related injuries in the pediatric population include head/facial, musculoskeletal, abdominal, and spinal trauma (Centers for Disease Control and Injury Prevention, 2012; Injury Surveillance Workgroup on Falls, 2006; Lallier et al., 1999).

Lastly, while there has been an increase in pediatric fall research and prevention efforts over the last few decades, such endeavors remain disproportionally small in comparison to efforts associated with the elderly (Koppolu, 2014; Leventhal, Martin, & Asnes, 2010; Unni, Locklair, Morrow, & Estrada, 2011). Moreover, few studies consider fall-related injury across all ages (Granacher, Muehlbauer, Gollhofer, Kressig & Zahner, 2011; Injury Surveillance Workgroup on Falls, 2006; Malta et al., 2012; Rozycki & Maull, 1991; Thierauf, Preub, Lignitz, Madea; 2010).

2.5 Falls in Young and Middle-Aged Adult Populations

Understanding fall-related injury patterns in young and middle-aged adults, those 19-64 years, becomes more complicated as vital information related to precipitating factors or the mechanism of injury is frequently under-reported (Injury Surveillance Workgroup on Falls, 2006). Not surprising, injuries from falls in this age group are often occupationally related as this population cohort constitutes the majority of the workforce (National Institutes for Occupational Safety and Health, 2004). Furthermore, gender differences are more pronounced in this age group. Men incur injuries as a result of falls from ladders or roofs, whereas women experience falls more from tripping or slipping (Injury Surveillance Workgroup on Falls, 2006).

One particular study comparing falls in young (20-45 years), middle-aged (46-64 years) and older (≥ 65 years) community-dwelling adults found significant differences among the age groups with respect to the causality (Talbot et al., 2005). Younger and middle-aged adults experienced more falls while engaged with physically-rigorous or sport-related activities; whereas older adult falls were associated more with conventional ADL activity and ambulation. Of significance, Kool, Amertunga & Robinson (2012) reported an increased risk for falls among young and middle-aged adults taking two or more medications, which has been an established finding in older adults (>65 years). Moreover, while numerous publications address alcohol-related traumatic injury, these findings remain under-represented in the fall-specific literature relative to fall risk assessment and prevention (Shults, Elder, Hungerford, Strife & Ryan, 2009; Stewart et al., 2003; World Health Organization, 2007).

2.6 Falls in Senior Adult Populations

According to the CDC (2013), one in three older adults, those ≥ 65 years, incur a fall each year. Of those who fall, approximately 30% will sustain a serious injury

(Centers for Disease Control and Injury Prevention, 2013). According to Sleet et al., (2008), hip fractures are among the most common injury incurred, with over 300,000 annual reported cases. Also, traumatic brain injury (TBI) accounts for 46% of the fall-related deaths in this population (Centers for Disease Control and Injury Prevention, 2013). Differences in fall rates and fall-related injuries based on gender are noted in this age group, with the frequency of falls and hospitalization rates higher in the cohort of women (Centers for Disease Control and Injury, 2013; Hartholt, Stevens, Polinder, van der Cammnen, & Patka, 2011). Additionally, unique to this population is the fear of falling which causes a decreased level of physical activity, subsequently leading to a decrease in mobility, balance, and overall physical fitness (Friedman, 2002; Tinetti, Mendes de Leon, Doucetter, & Baker, 1994). The net result is an increased risk of falling. Common factors cited by the CDC (2013) as increasing older adults fall risks include; physical changes associated with the aging process, functional impairments, chronic health conditions, polypharmacy, and home hazards. Lastly, the few studies that address extrinsic factors associated with elderly falls have done so in a limited context focusing on home hazards, foot ware, and the like.

2.7 Fall risks

Risks factors linked to accidental falls are categorized as being intrinsic or physiologically based, and extrinsic or socioenvironmental based (Bergland, 20102; Bueno-Cavanillas et al., 2000; Currie, 2006; Injury Surveillance Workgroup on Falls, 2006; Feldman & Chaudhury, 2008). Examples of fall-related intrinsic risk factors include; age, gender, ethnicity, physical and cognitive impairments, history of falling, as well as polypharmacy (Bergland, 2012; Currie, 2006; Injury Surveillance Workgroup on Falls, 2006; Feldman & Chaudhury, 2008). Physiological risk factors associated with aging impact older adult populations, those 65 years and older (Bergland, 2012). Examples of fall-related extrinsic risks factors include; lifestyle, home environment, and occupational exposures (Bergland, 2012; Currie, 2006; Injury Surveillance Workgroup on Falls, 2006; Feldman & Chaudhury, 2008). Extrinsic fall-related risk factors are felt to have a more dominant role in pediatric and younger and middle-aged adult populations. Extrinsic risks have less of an impact in senior populations, as intrinsic factors, especially chronic illness, become more pronounced (Bergland, 2012). Also, there are two extrinsic fall risk factors considered unique to older adult populations; living along and the fear of falling (Bergland, 2012, Elliot, Painter & Hudson, 2009; Garcia, Marciniak, McCune, Smith, & Ramsey, 2012). There has been recent attention given to these two social-based risk factors as their impact on older adult fall rates is substantial.

While accidental falls are considered to be preventable, contributory factors are often multifactorial (Bergland, 2012; Gillespie et al., 2012; Injury Surveillance Workgroup on Falls, 2006; Sleet et al., 2008; Vellas, Wayne, Garry, & Baumgartner, 1998). Therefore, certain determinants are more easily modifiable than others. Current literature suggests that situational, behavioral, and environmental factors may be among the most important determinants of fall-related risks in persons of all ages (Bergen et al., 2008; Boland et al., 2005; Cubbin et al., 2008; Feldman & Chaudhury, 2008; World Health Organization, 2008; World Health Organization, 2009).

There is a multitude of fall risk assessment tools and prevention programs designed for community-dwelling adults. Useful fall screening programs include elements of medical, social, and in-home or environmental assessments, leading to prevention initiatives that are multifaceted and tailored to mitigate identified risk factors (Gates, Lamb, Fischer, Cooke & Carter, 2008; Pynoos, Steinman, Ngyyen, & Bressette, 2012; Shubert, 2011). Attention to fall risk assessment in children has primarily centered on the hospital setting. More recent efforts have established pediatric-specific assessment tools for use in the community setting (McWillimas, 2011). In general, fall risk assessments for children and working adults focus on environmental factors associated with home, recreational and work settings (Borse et al., 2008; National Institutes for Occupational Safety and Health, 2004; Pomerantz, Gittelman, Hornung & Husseinzadeh, 2012).

Race and ethnicity.

Studies that have explicitly addressed race and ethnicity in association with falls have done so for a defined age group or injury type. Within the falls literature, there is evidence that indicates older adult fall-related injury rates are higher in Non-Hispanic White American females than in African Americans women (Hu & Baker, 2009; Faulkner et al., 2005; Stevens & Delllinger, 2002). Also, Hispanic ethnicity is linked with lower fall-related injury deaths. However; gender, age, and socioeconomic status appear to modify this finding (Landy et al., 2011; Landy, Mintzer, Dearwater, Graygo, & Schulman, 2012; Stevens & Delllinger, 2002). Furthermore, many of these studies recommend that future inquiries specifically address race and ethnicity in the evaluation of fall risk factors, mechanisms of injury, and injury outcomes (Hu & Baker, 2009; Injury Surveillance Workgroup on Falls, 2006; Landy, Mintzer, Silva, & Schulman, 2011; Sleet et al., 2008).

Socioeconomic status.

There remains a significant gap in the fall-related literature regarding population disparities associated with socioeconomic status (SES; Bohannon et al., 1999; Grisso et al., 1992; Hanlon et al., 2002; Heesch et al., 2008; Stevens & Sogolow, 2005). Studies examining the relationship between SES and fall-related injury risks are linked more with children than adults, despite the preponderance of falls research focused on older adults. Furthermore, many historical investigations concentrated on the individual or microlevels of SES, such as social status, whereas current efforts are addressing macrolevel social conditions, such as environmental deprivation (O'Campo, Rao, Gielen, Royalty, & Wilson, 2000). While there remain mixed results, a sizeable body of pediatric falls literature suggests a positive relationship between SES and childhood injury, and more specifically, fall-related injury risks (Birken & MacArthur, 2004; Hong et al., 2010; Kamala et al., 2014; O'Campo et al., 2000; Peden et al., 2008; World Health Organization, 2009; Williams et al., 1997). The relationship of SES and fall-related injury in adult populations has not been as extensively studied, and published findings remain varied (Basta et al., 2007; Lyons et al.,2003; Siracuse et al, 2012).

An individual's relative position on a social-economic scale, or their SES, is determined by a variety of factors such as income, education, occupation, and place of residence. It is well documented that individuals having lower levels of SES are more susceptible to disease and injury, in addition to a lower quality of life and higher overall mortality (Galea, Hoggatt, DiMaggio, & Karpati, 2011; Krieger, Williams & Moss, 1997; Link & Phelan, 1995; Machenbach et al., 2008; Singh & Siahpush, 2002; Stringhini et al., 2010; Syme & Berkman, 1976). Although the predominance of historical research has focused on individual-level health risk factors, more contemporary studies have recognized the importance of social influences on health, specifically how they may operate relative to where people live (Anderson, 1997; Davey-Smith, Hart, Watt, Hole, & Hawthrone, 1998; Diez-Roux, 2001). Area-level, or neighborhood effects on health, have become recognized as noteworthy determinates of health disparities (Mackenbach et al., 2008; Messer et al., 2006; Sampson, Morenoff, & Gannon-Rowley. 2002). Moreover, indices of neighborhood SED are often used as a proxy for individual SED (Schuurman, Bell, Dunn & Oliver, 2007).

Relative deprivation signifies a state of disadvantage experienced by individuals or communities in relation to their contiguous population (Schuurman et al., 592). Neighborhood deprivation can further be defined by primary constructs based on measurements of social position and material access (Carstairs, 1995; Sampson, Raudenbush, & Earls, 1997; Schuurman et al., 2007). Measures of social position such as levels of family/community support, rights of community membership, and influence over the environment, are difficult to ascertain due to complexities associated with data collection (Schuurman et al., 2007; van Vuuren, Reijneveld, van der Wal & Verhoeff, 2014). Therefore, surrogate measures of income/poverty and education constructs are often used to denote neighborhood social deprivation (Krieger et al., 1997; Messer et al., 2006). On the other hand, measures of material deprivation which center on resource access, for example, housing, education, and employment, are readily accessible through population census data (Krieger et al., 1997; Schuurman et al., 2007; van Vuuren et al., 2014).

Research assessing neighborhood effects on health outcomes typically integrate multiple domains of SED. Within the epidemiologic and social science literature, the most widely used domains of neighborhood SED include; poverty /income, race/ethnicity, education, employment, occupation, housing/crowding, and residential stability (Krieger et al., 1997; Messer et al., 2006; Schuurman et al., 2007; van Vuuren et al., 2014). And while poverty appears as the most common socioeconomic construct employed in research, its definition remains variable. Most often poverty is defined by; (1) percentage of individual or household income below the federal poverty level (FPL), (2) percentage of public assistance, and (3) percentage of female-headed households with dependent children (Sampson et al., 1997; Krieger et al., 1997; Messer et al., 2006; van Vuuren et al., 2014).

As previously mentioned, direct or indirect measures of social position and material access are easily obtained through population census data. Within the U.S., most research investigating health outcomes relative to place-based effects rely on neighborhood units as defined by the U.S. Bureau of Census (Krieger et al. 1997; Messer et al., 2006; Schuurman et al., 2007). Census data is the most widely used and accepted methodology, given its accessibility and user-friendliness, (Aveyard, Manaseki &

Chambers, 2002; Krieger et al., 1997; Kreiger, Chen, Waterman, Soobader, Subramanian & Carson, 2003; Messer et al., 2006; Sampson et al., 2002; Schuurman et al., 2007).

Urban versus rural environments.

Globally, urban living has become the dominant mode of dwelling with the balance of urban-rural residence varied across and within regions (World Health Organization, 2008). In general, residents of metropolitan areas have better access to healthcare resources than residents of rural areas. However; environmental vulnerabilities correlated with urbanization pose significant health challenges, particularly for populations that are socially and economically deprived (Marmot et al., 2008; Meit et al., 2014; World Health Organization, 2008). Increases in communicable diseases, environmental pollutants exposure, chronic illness, substance abuse, depression, violence, and traumatic injury are examples of health-related issues associated with urbanization (Beck, 2011; Cubbens et al., 2000; Srimivasan et al., 2003; Williams, 2013; World Health Organization, 2008).

With public policy and investments fueling the urban-led growth paradigm, rural community access to resources necessary for good health are increasingly compromised (World Health Organization, 2008). Rural settings are experiencing unstable ecologies, scarcity of livelihood opportunities, inferior physical infrastructures, and insufficient healthcare services. All of the aforementioned contribute to poor health outcomes, especially for the economic and socially disadvantaged (Beck, 2011; Hartely, 2004; Meit et al., 2014; Srinivasan et al., 2003; Williams, 2013; World Health Organization, 2008). Furthermore, numerous reports indicate a higher incidence of risk-taking behaviors in rural-dwelling populations. Such behaviors include smoking, excessive alcohol consumption, inactivity, and poor nutrition (Gamm, Hutchinson, Dabney, & Dorsey, 2003; Hill , You & Zoellner, 2014; Jones, Parker, Ahearn, Mishra, & Variyam, 2009; Meit et al., 2014; National Center for Health Statistics, 2013). Lastly, there is considerable research demonstrating higher rates of age-adjusted mortality, disability, chronic disease, and mental health issues associated with unintentional injury (Boland et al., 2005; Cubbin et al., 2000; Gamm et al., 2003; Jones et al., 2009; Meit et al., 2014).

2.8 Fall Prevention

Many studies have addressed the quality, relevance and effectiveness of various fall prevention initiatives (Corrieri, Heider, Riedel-Heller, Hill-Westmoreland, Soeken, & Spellbring, 2002; Matchinger & Kong, 2011; Gates, Lamb, Fisher, & Cooke, 2007; Moyer, 2012; Sleet et al., 2008). Recent systematic reviews and meta-analysis of literature identify the need for additional research associated with multifactorial assessments and targeted interventions for fall prevention (Corrieri et al., 2011; Gates et al., 2007; Klores, 2012; Sleet et al., 2008). Referenced in the literature are a variety of fall risk assessment tools although the majority concentrate on intrinsic risk factors (those that are physiologically based). And when included, extrinsic fall- risk factors are typically limited to the built environment, such home hazards (Bongue et al., 2011; Gates et al., 2007; Renfro & Fehrer, 2011). Also, the published literature on fall risk assessment in pediatric populations remains limited (Child Health Corporation of America Nursing Falls Study Task Forces, 2009; McWilliams, 2011). As a result, fall prevention programs remain designed with a generic focus on older adults across a variety of environments.

Few studies consider social and geographic factors involved in the etiology of injurious falls throughout the life course.

2.9 Summary

Within the United States, accidental falls are the principal cause of all non-fatal injuries, and the third leading cause of all fatal injuries (Bergen et a., 2007; Centers for Disease Control, 2014). Though persons of all ages have a risk for falling and thus sustaining a fall-related injury, the most vulnerable are the youngest and oldest populations (Injury Surveillance Workgroup on Falls, 2006).

Falls are among the top causes of fatal injuries in children of all ages and is the leading mechanism of nonfatal injury in children less than 15 years old (Bores et al., 2008). Environmental factors are often associated with pediatric falls and findings in the literature support that height and landing surface significantly influence the severity of injury (Haney et al., 2012; Harris et al., 2014; Pomerantz et al., 20012, Unni et al., 2012). Moreover, while pediatric falls research has historically centered on types of falls, contemporary studies are focused on injury patterns among the various age cohorts, recognizing that stages of physical and psychosocial development greatly influence injury risks, patterns, and outcomes (Tracy et al., 2013; Unni et al., 2012).

A comprehensive understanding of fall-related injury in younger and middle-aged adults is lacking as information associated with precipitating factors or mechanisms of injury are frequently under-reported (Injury Surveillance Workgroup on Falls, 2006). Injuries related to falls in this population cohort are often occupationally related, as they comprise the majority of the workforce (National Institutes for Occupational Safety and

Health, 2004). Also, a recent observation associated with this age group is an increased risk of falling for those adults taking two or more medications, a more common finding in older or senior adults (Kool et al., 2012). Additionally, a gap identified in the fall-specific literature is the under-representation of alcohol-related fall injuries in the context of fall risk factors, risk assessments, and prevention initiatives (Shults, Elder, Hungerford, Strife & Ryan, 2009; Stewart et al., 2003; World Health Organization, 2007).

Of those older adults who fall, a third will sustain serious harm (Centers for Disease Control and Injury Prevention, 2013). The most common injuries are hip fractures and head injuries. Traumatic brain injuries account for 46% of the fall-related deaths in this population cohort (Centers for Disease Control and Injury Prevention, 2013; Sleet et al., 2008). Gender differences are more pronounced regarding fall rates and fall-related injuries, as older women have a higher incidence of falls as well as higher hospitalization rates (Centers for Disease Control and Injury Prevention, 2013; Hartholt et al., 2011). Additionally, there are several unique fall risk factors associated with older adults (Bergland, 2012; Elliot et al., 2012; Garcia et al., 2012; Centers for Disease Control and Injury Prevention, 2013; Friedman et al., 2002, Tinetti et al., 1994).

Classified as being intrinsic or physiologically based, and extrinsic or socioenvironmentally based, fall-related risk factors are nonetheless multifactorial in nature (Bergland et al., 2012; Currie, 2006; Injury Surveillance Workgroup on Falls, 2006). Though accidental falls are considered preventable, certain determinants are more easily mitigated than others. Current literature proposes that situational, behavioral, and environmental factors may be the most significant determinants of fall-related risks in all ages (Bergen et al., 2008; Boland et al., 2005; Cubbins et al., 2008; Feldman & Chaudhury, 2008; World Health Organization, 2008; World Health Organization, 2009).

Additional research is needed in which socioeconomic factors and population demographics of gender, age, race, and ethnicity are included in the comprehensive evaluation of fall-related injury (Injury Surveillance Workgroup on Falls, 2006; Nickleh & Taylor, 2014; Sleet et al., 2008). Interestingly, the majority of publications which address SES as a risk factor for fall injury are associated with pediatric populations despite the prevalence of falls research focused on the elderly. While results appear to be conflicted, there is a sizable body of pediatric literature which suggests a positive association between low SES and childhood fall-related injury (Birken & MacArthur, 2004; Hong et al., 2010; Kamala et al., 2014; O'Campo et al., 2000; Peden, 2008; World Health Organization, 2009, Williams et al., 1997). Also, although not as prolific, published findings linking SES to fall-related injury in adult populations remain varied (Basta et al., 2007; Lyons et al. 2003; Siracuse et al., 2012).

At large, populations residing in urban geographies have enhanced access to healthcare resources than those living in rural settings. Nevertheless, there remain environmental vulnerabilities which pose increased health risks, including traumatic injury, particularly for population cohorts that are socially and economically disadvantaged (Beck, 201; Hartley, 2004; Marmot et al., 2008; Meit et al., 2014; Srinivasan et al., 2003; Williams, 2013, World Health Organization, 2008). In addition, there are numerous publications which associate higher rates of age-adjusted mortality, disability, chronic disease, and injury in rural settings (Boland et al., 2005; Cubbin et al., 200; Gann et al., 2003, Jones et al., 2009; Meit et al., 2014).

Lastly, there are numerous publications which speak to the quality, relevance and effectiveness of fall prevention initiatives (Corrieri et al., 2002; Matchinger & Kong, 2011; Gates et al., 2007; Moyer, 2012; Sleet et al., 2008). The preponderance of fall assessment tools and prevention programs are centered on intrinsic fall risk factors; and when included, extrinsic risk factors remain limited in scope (Bongue et al., 2011; Gates et al., 2007; Renfrom & Fehrer, 2011). Also, there is a paucity of fall risk assessment tools for the pediatric population (Child Health Corporation of America Nursing Falls Study Task Forces, 2009; McWilliams, 2011). Furthermore, few studies take into consideration fall risk factors throughout the life course. Consequently, many fall prevention programs are designed with a generic focus on older adults and immediate environment.

CHAPTER 3: METHODOLOGY

3.1 Introduction

This study applied a retrospective, ecologic population-based cohort methodology in the assessment of fall-related injury in the state of New Jersey for the five-year period 2009-2013. Ecological study designs in social epidemiology allow for the study of health risk-modifying factors, or other health outcomes among geographically-based population cohorts (Krieger, 1992; Krieger 2001; Morgenstern, 1985). The consideration of ecologic variables in epidemiologic research further advances the emerging paradigm that holds social determinates as pivotal mediators of health. Also, ecologic approaches to place-related health assessments are in alignment with the international and national population health management initiatives by patterning health, disease, and well-being (Krieger 2009; Solar & Irwin, 2010; U. S. Department of Health & Human Services, 2013). Although such a methodology predisposes research to aggregation bias, ecological or multilevel causal studies maintain tremendous epidemiological value as they support large-scale comparisons between groups of people and allow for an initial examination of the status and needs of communities (Diez-Rioux, 2001; Krieger, 2001; Krieger, 2009; Morgenstern, 1985; Sampson et al., 2002; Wakefield, 2008).

3.2 Study Design

A state-wide hospitalization registry was utilized to explore fall-related injuries over the course of a five-year period within the state of New Jersey. Access to over 12.3 million hospital records (approximately 2.48 emergency department visits and 1.4 million hospital stays per year), in combination with U.S. Census data, allowed for a fairly rigorous ecological study of falls and fall-related injuries. Patient-level information and hospital data were used to estimate the age-specific incidence of injury related to falls across young and old age cohorts. New Jersey census data was accessed to obtain demographic characteristics, such as levels of urbanization and indicators of socioeconomic status, to further support an ecological analysis of variation in the age-specific incidence of fall-related injury in relation to community socioenvironmental factors.

The central research question focused on differential vulnerability to subacute and acute fall-related injury related to age, gender, and ecological factors of population size, population density, and SED. The study population consisted of the 8.8 million residents as of 2010, residing in 566 county civil divisions (CCDs) in the state of New Jersey. Specific age and gender cohorts were employed to facilitate the inquiry of fall-related injury, taking into consideration mechanisms and injuries as described in current falls literature. Of note, while pediatric injury research utilizes age groupings that differ from those in this study, the specific age cohorts used strengthen the assessment of fall-related injury across the life-course, which was an aim of this study (Borse et al., 2008; Centers for Disease Control and Injury Prevention 2013; Centers for Disease Control and Injury Prevention 2014; Chen et al., 2009; Tracey et al., 2013). Hence, this study implemented age and gender-specific cohorts (Table 3).

Table 3: Patient Demographic Cohorts

Age Cohorts	Gender Cohorts
Pediatric: - ≤ 14 years	Male
Adolescent – Young Adult: - 15-24 years	Female
Middle-Aged Adult: - 25 -44 years - 45-64 years	
Senior Adult: - 65-84 years - > 85 years	

3.3 Data Sources

Data sources included the New Jersey state-wide hospital registry for the years 2009 through 2013, the 2010 decennial census for New Jersey for population demographic data, and the 2010 American Community Survey, supplemental to the 2010 decennial census for population socioeconomic data.

New Jersey state-wide hospital registry.

The hospital registry, formally titled the New Jersey Discharge Data Collection System (NJDDCS), is managed by The Office of Healthcare Quality Assessment under the New Jersey Department of Health (New Jersey Department of Health, 2016). Based on the universe of New Jersey acute care hospitals' uniform billing data, the registry contains information associated with ED visits, outpatient surgery, same-day surgery, and inpatient encounters (New Jersey Department of Health, 2016). More specifically, the hospital registry contains information associated with patient demographics, diagnosis and procedure codes following the International Classification of Diseases (ICD), as well as billing information and charges for services provided (New Jersey Department of Health, 2016). De-identified patient-level and hospital stay data information obtained from the registry included; age, gender, fall injury specified by ICD injury mechanism and diagnosis codes, and emergency department visit versus hospital admission. For each of the 566 county civil divisions (chiefly townships and municipalities) in the state of New Jersey, hospitalization count data was further aggregated by age cohort and gender.

United States decennial census.

Within the United States, a census is conducted every ten years as required by law. The primary purpose of the decennial census is the collection and provision of population demographic data. Decennial census data is aggregated and reported at various geographic levels. The use or application of census data in ecologic research provides scientific rigor, as it gives a complete enumeration of the population by town, versus partial samples that get aggregated having large confidence intervals and increased measures of error.

The state of New Jersey's census geographic regions includes county and county subdivisions. As there are no overlapping jurisdictions or unincorporated areas in the state, all New Jersey county subdivisions are considered minor civil divisions (New Jersey Department of Labor, 2000). There are 566 governing municipals or county civil divisions within the state (New Jersey State Department of Labor, 2000). New Jersey statute further distinguishes between municipalities, which refer to cities, towns, boroughs as well as villages, and townships. Of the 566 county civil divisions, there are

320 municipalities and 246 townships (New Jersey State Department of Labor, 2000). This study utilized 2010 decennial census data at the county civil division (CCD) level to estimate residential population size and residential population density, as well as key social and economic characteristics of CCD residential populaces (see Appendix A for a listing of New Jersey's 2010 census civil divisions).

American Community Survey.

Administered on an ongoing basis, the American Community Survey (ACS) is a vital adjunct to the decennial census, providing more detailed information about American communities with respect to employment, occupation, education attainment, housing, and other socioeconomic topics (U. S. Census Bureau, 2014). American Community Survey data is estimated at various geographic summary levels, similar to the decennial census. Measures included in both SED indices were obtained from the 2010 American Community Survey, which provided supplemental socioeconomic data to the 2010 state census data.

3.4 Protection of Human Subjects

This research initiative did not involve human subjects. Approval for the study protocol was requested via a letter of determination and submitted to the Human Research Protection Committee of the Office of Research, Drexel University. Access to the New Jersey hospital registry was supported by the administrator of a data user agreement between the New Jersey Department of Health and Cooper University Healthcare, the organization in which two of the study’s co-investigators were employed. Data points collected from the state-wide hospital registry were de-identified, as well as aggregated and analyzed according to the year of occurrence, not the specific service date. Moreover, the New Jersey Department of Health shielded personal health information in accord with its departmental Institutional Review Board determination.

3.5 Study Variables

Fall-related injury.

The dependent variable of this study was fall-related injury, incurred in the community setting, and resulting in an emergency department (ED) visit or hospitalization. Fall injury cases in the state of New Jersey during 2009-2013 were identified through the state hospital registry's Uniform Billing data using assigned principal diagnosis codes and injury mechanism codes from the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) system. Fall-related injury rates [rate per thousand (RPK)] for each of New Jersey's 566 CCDs were ascertained utilizing collated individual-level hospital registry data and decennial census data. Also, fall-related injury rates were further calculated for gender and age cohorts.

Lastly, fall-related injuries were classified according to nature of acuity. Subacute fall-related injuries were those that resulted in an ED visit without admission to the hospital. Acute fall-related injuries were those that required a hospital admission or a minimum of a 24-hour stay. Acuity data was included in the analysis of fall-related injury across gender and age cohorts.

Population size and population density.

The independent variables in this study reflecting levels of urbanization were residential population size and density. Population size represented the number of residents by count, and population density signified the number of residents by count per square mile. Urbanization is commonly defined as the proportion of a given population residing in defined areas, though other characterizations may include aspects of the built environment and social supports (Dahly & Adair, 2007; Gibbs, 1966; Williams, 1985). For the purpose of this study, population size and density were used to indicate the level of urbanization given the ease of estimation from census data.

Measures of socioeconomic deprivation.

Two indices used to measure neighborhood socioeconomic deprivation included the Townsend Index (TSI) and the Index of Neighborhood Concentrated Disadvantage (NCD). Developed in the 1980's as an area-based measure of material deprivation, the TSI is an accepted indication of neighborhood SED centering on a community's position on an economic scale relative to income and wealth (Aveyard et al., 2002; Boarini & d'Ercole, 2006; Krieger et al., 1997; Messer et al., 2006; Schuurman et al., 2007). Consisting of variables associated with unemployment, overcrowding, and ownership of car/home, the TSI can be easily calculated using census data.

The Index of Neighborhood Concentrated Disadvantage (NCD) is a well-established indicator of the relative poverty of communities used to measure SED in the U.S. (Carroll-Scott et al., 2013; Krieger, 1992; Sampson, Morenoff & Felton, 1999; Wang & Arnold, 2008; Wight, Cummings, Miller-Martinez, Karlamangla, Seeman, &

Aneshensel, 2008). Sampson (1997) demonstrated that the factors of poverty; use of public assistance, female-headed households, unemployment, and density of children, were associated with each other, and collectively establish a proxy for community economic disadvantage. This measure of concentrated poverty has been widely used by sociologists in the study of adolescent violence, crime, and infant mortality. While some measures of NCD overlap with the TSI, for example, household unemployment, the NCD principally focuses on socially and culturally marginalized subpopulations. Similar to the TSI and other indices of neighborhood disadvantage, the NCD is calculated using census data (Association of Maternal and Child Health Programs, 2014; Carroll-Scott et al., 2013; Wang & Arnold, 2008).

Considered to be compositional indices, both the TSI and NCD employ multiple indicators of SED to strengthen the validity and reliability of the measured construct (Association of Maternal and Child Health Programs, 2014; Curtis, 1990; Gordon, 1995; Krieger, 1992; Kreiger et al., 2003; Messer et al., 2006; van Vuuren et al., 2014). Also, it has been demonstrated that both indices are highly correlated with each other, regardless of geographic scale and location (Cartairs, 1995; Messer et al., 2006; Wang & Arnold, 2008).

In application, the particular measure for a defined area is the sum of its standard deviation (Z-scores) for each of the variables comprising the SED measure. Therefore, the index is providing a scale for ascertaining how far on the statistical margin a defined neighborhood or delineated area is among the sample of areas, given the statistical variation of each SED variable, for a given distribution of areas. A higher score for either index is considered to be reflective of greater neighborhood deprivation. Shown in Table 4 are variables associated with the Townsend Index and the Index of Neighborhood Concentrated Disadvantage.

Table 4: Indices of Area-Level, Neighborhood Socioeconomic Deprivation

Townsend Index: Measure	**Construct**
% Rental Housing	Residential
% Households with Crowding (# persons > # rooms)	Social
% Households without Car Ownership	Economic
% Household where Head of Household is Unemployed	Economic
Neighborhood Concentrated Disadvantage Index: Measure	**Construct**
% Households where Head of Household is Unemployed	Economic/Residential
% Household below U.S. Federal Poverty Level	Economic
% Family Households Receiving Welfare Payment	Economic
% Households with Single Parent Dependents	Social
% Minority Households	Cultural Marginality

3.6 Statistical Analysis

This study explored how fall-related injuries vary from urban and rural environments, and further assessed variation of fall-related injury rates regarding levels of SED for specific population cohorts. Data analysis was conducted in three phases; (1)

univariate analysis, (2) bivariate and partial regression analysis, and (3) multivariate regression analysis.

Descriptive statistics or measures of central tendency and distribution were used to summarize state-specific population and hospital-level data associated with fall-related injury within the state of New Jersey. The state-wide hospitalization registry was used to approximate the age-specific incidence of subacute and acute fall injuries for each gender for the entire state for the period of 2009 through 2013 and compared with the population at risk as enumerated in the 2010 decennial census. Additionally, the age-specific incidence of subacute and acute fall-related injury requiring emergency department treatment or hospitalization by gender was approximated for New Jersey's 566 county civil divisions for the same period 2009 through 2013.

This study further investigated whether the socioenvironmental factors hypothesized to predict the incidence of fall-related injury, specifically population size, density, and socioeconomic deprivation, were confounded with each other. Statistical procedures used to test for associations among these ecologic variables and fall-related injury rates included bivariate correlational analysis and linear regression analysis. In light of the crucial importance of age and gender on fall incidence, separate models were analyzed for each age-gender specific cohort.

Multivariate regression analysis was utilized to assess effect modification of population size, population density, and SED on the fall-related injury, as well as associations with age and gender by testing for linearity in the model. Of note, four distinct CCDs were excluded in regression models as fall-related injury rates were unstable due to missing data and considerably small populations. Also, robust standard errors were used to provide for more conservative tests for statistical significance, given the expectation that ecological data such as that analyzed in this study, likely violate the assumptions of homoscedasticity. To explain further, spatial-ecological data by definition share spatial proximity among adjacent towns; thus, the demographic variables that are predictors of model outcomes likely have correlated error terms. Also, the critical test of <0.05 was used to establish statistical significance for regression coefficients.

Multivariate statistical modeling.

Figure 2 provides a representation of the interrelationship of residential population size, residential population density, and SED on fall-related injury. The figure depicts three separate, direct effects on positive relationships between fall-related injury and county civil division residential-level population size, density, and SED as indicated by two indices; the Townsend Index and the Neighborhood Concentrated Disadvantage. A significant question remained whether SED was a confounder or effect modifier of the relationship between SED and fall-related injury. Included in the diagram is an interaction term indicated by the pathway from residential population size and residential population density to SED. The empirical evidence in support of SED as a confounder versus an effect modifier would be observed in the size, direction, and statistical relevance of the pathways p(X1*X3) and p(X2*X3) which are representative of a conjoint effect of residential population size, density, and SED.

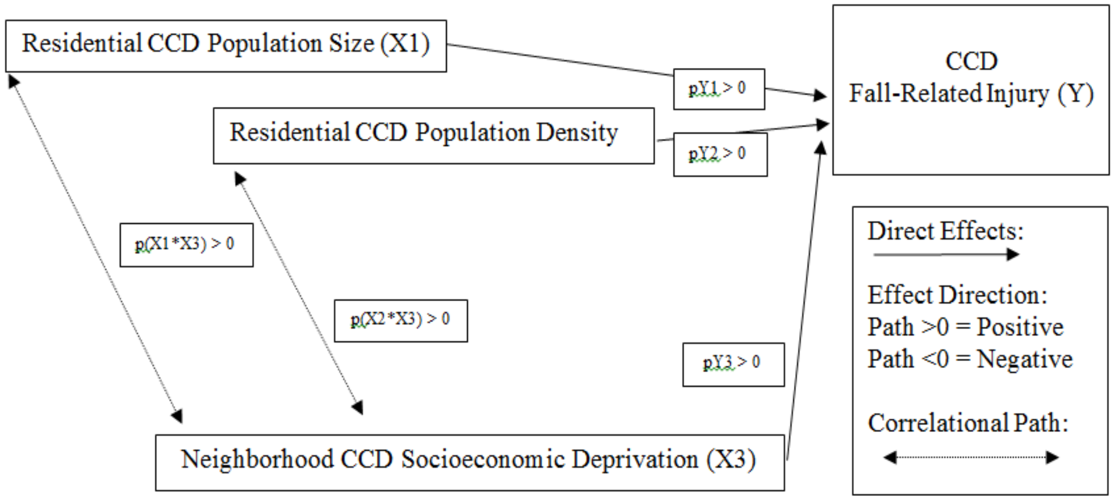

Figure 2: Ecological Model of Fall-Related Injury

Ecological models include geographic regions so as to adjust for level of urbanization and SED. This approach provides a means for estimation of community characteristics. The statistical software used to estimate models and conduct analysis was STATA®, version 13.

Representation of the mathematical model and identified parameters used to estimate fall-related injury assuming a linear relationship between population size, density, SED and the outcome variable of fall-related injury is presented below:

Ecological Fall-Related Injury Linear Regression Equation

Yij = a + b1X1 + b2X2 + b3X3 + Eij where:

Yij = Dependent Variable Fall-Related Injury Rate (Y)

Age and Gender Cohorts (i)

County Civil Divisions 1-566 (j)

a = Intercept or Constant; expected mean value of Y when X1, X2, X3 (when SED state average is 0) = 0

b = Coefficients of Variables; change in the predicted value of Y per unit of change in X

X1 = County Civil Division Population Size

X2 = County Civil Division Population Density

X3 = County Civil Division Socioeconomic Deprivation

Eif = Error Term (Residual), Unexplained Variance

To test the linearity of the relationship between fall injury rates and population size, or fall injury rates and population density; binary or dummy variables were created from quintile subsets of the 566 New Jersey CCDs. If these relationships were found to be linear, the coefficients for each quintile would be found to be equivalent. The following statistical model was employed to assess the potential for non-linear relationships among population size, population density, and SED on fall injury rates:

Ecological Fall-Related Injury Non-Linear Regression Equation

Yij = a + b1X1 + b2X2 + b3X3 + b4X4 + b5X5 + b6X6 + b7X7 + b8Xb + b8X8 + b9X9 where;

Yij = Dependent Variable Fall-Related Injury Rate (Y)

Age and Gender Cohorts (i)

County Civil Divisions 1-566 (j)

a* = Intercept or Constant; reflects the mid-quintile for both population size and density

b = Coefficients of Variables; change in the predicted value of Y per unit of change in X

X1 = County Civil Division Socioeconomic Deprivation

X2 = County Civil Division Population Size; quintile ≤ 20k

X3 = County Civil Division Population Size; quintile 21-40k

X4 = County Civil Division Population Size; quintile 61-80k

X5 = County Civil Division Population Size; quintile ≥81k

X6 = County Civil Division Population Density; quintile ≤ 20k

X7 = County Civil Division Population Density; quintile 21-40k

X8 = County Civil Division Population Density; quintile 61-80k

X9 = County Civil Division Population Density; quintile ≥81k

Eif = Error Term (Residual), Unexplained Variance

*Note: When using dummy (or binary) variables to represent segments of a distribution, such as the <20k percentile, 21- 40k percentile, etc., all classes or segments of the distribution as independent variables cannot be included; rather one group must be excluded in order for the regression equation to be properly estimated. Thus, the group or subjects associated with the excluded class are represented in the intercept.

3.7 Summary

This study adopted a retrospective, ecologic population-based cohort methodology in the evaluation of fall-related injury over a five-year period within the state of New Jersey. The research question centered on differential vulnerability to fall-related injury with respect to age, gender, and ecologic covariates of population size, density, and SED. The study population was inclusive of the 8.8 million residents residing within New Jersey’s 566 county civil divisions as of 2010. Data sources included the New Jersey 2010 decennial census, the 2010 American Community Survey and the state-wide hospital registry for the years 2009 through 2013. Census data was utilized at the county civil division level to approximate population size and residential density. Measures of SED were attained from both the census data as well as the Community Survey and were represented by two distinct indices, the Neighborhood Concentered Disadvantage Index and the Townsend Index.

Data analysis consisted of three phases. The first phase used univariate analysis or measures of central tendency and distribution to summarize state-specific population and hospital-level data. The second phase applied bivariate and partial regression analysis to further assess further the correlation, or potential for confounding, among the ecologic covariates of population size, density, and SED. Lastly, multivariate statistical modeling was utilized to assess for effect modification among population size, density, and SED, as well as associations with age and gender. Of note, ecologic models included geographic regions, or the 566 count civil divisions, to account for the varying levels of population size, density, and SED.

CHAPTER 4: ANALYTIC FINDINGS

4.1 Introduction

The discussion of analytical findings begins with descriptive statistics for study variables, followed by a discussion of linear regression results using two analytical strategies whereby the predictors are treated first as linear covariates, and secondly, as categorical predictors representing selected quintiles of population size and density among the universe of New Jersey towns (CCDs). Also, the combined net impact of predictor variables on fall-related injury rates will be described by age and gender cohort. Of note, research outcomes are organized initially according to subacute, then by acute fall-related injury for the respective gender and age groups.

4.2 Descriptive Statistics of Study Population: Independent Variables

Summarized in Table 5 are descriptive statistics used to assess central tendencies and distribution related to the demographic study variables for specific age and gender cohorts within New Jersey's 566 CCDs. Though New Jersey is a fairly populous state, there was significant variation, up to a ten-fold difference in magnitude, in population size among the 566 CCDs. The mean population size among the 566 municipalities was 15,533.4 residents by count, with a range of 989.9 to 54,807.4 residents. Comparably, New Jersey municipalities were widely diverse with respect to population density as the average population density among the 566 CCD's was 3,405.6 residents per square mile, with a range of 109.0 to 10853.2 residents per square mile.

Table 5: Demographic Predictors Based on the 2010 Decennial Census

COUNTY CIVIL DIVISION POPULATION SIZE, DENSITY AND SOCIOECONOMIC DEPRIVATION FOR NEW JERSEY BASED ON 2010 CENSUS AND AMERICAN COMMUNITY SURVEY				
VARIABLES:	Mean	Std. Error of Mean	5th Percentile	95th Percentile
Population size	15533.4	989.9	874.2	54807.4
Population Density	3406	223	109	10853
Neighborhood Concentrated Disadvantage	0.00	0.17	-4.05	8.41
Townsend Index	0.00	0.10	-2.62	4.84
% Population Below Federal Poverty Level	6.70	0.24	1.22	18.04
% Dependent Single Parent	21.91	0.52	8.11	47.39
% Public Assistance	1.71	0.08	0.00	5.36
% Household Below Federal Poverty Level	6.75	0.23	1.24	18.34
% Household Rental	24.97	0.75	5.21	62.31
% No Car	7.06	0.31	0.61	23.63
% Unemployed	7.17	0.13	3.36	12.63
% Minority	25.76	0.90	4.93	74.88

Depicted in Figure 3 is a heat map of residential population size and density within the state of New Jersey illustrating the significant diversity in place effect at the county civil division level. Centered near New York, Philadelphia, Trenton, and Atlantic City, in addition to the northern, central, and southern shore areas, are the metropolitan areas with the highest residential population. Conversely, primarily situated in the northwestern, southwestern, and central regions of New Jersey are the less populated areas of the state. Similarly, the metropolitan areas identified above are also the most densely populated areas of the state. Furthermore, the heat map reveals two distinct topographies based on the level of urbanization. The northern half of the state is comprised of more urban and suburban areas, whereas the southern half of the state is considerably more rural.

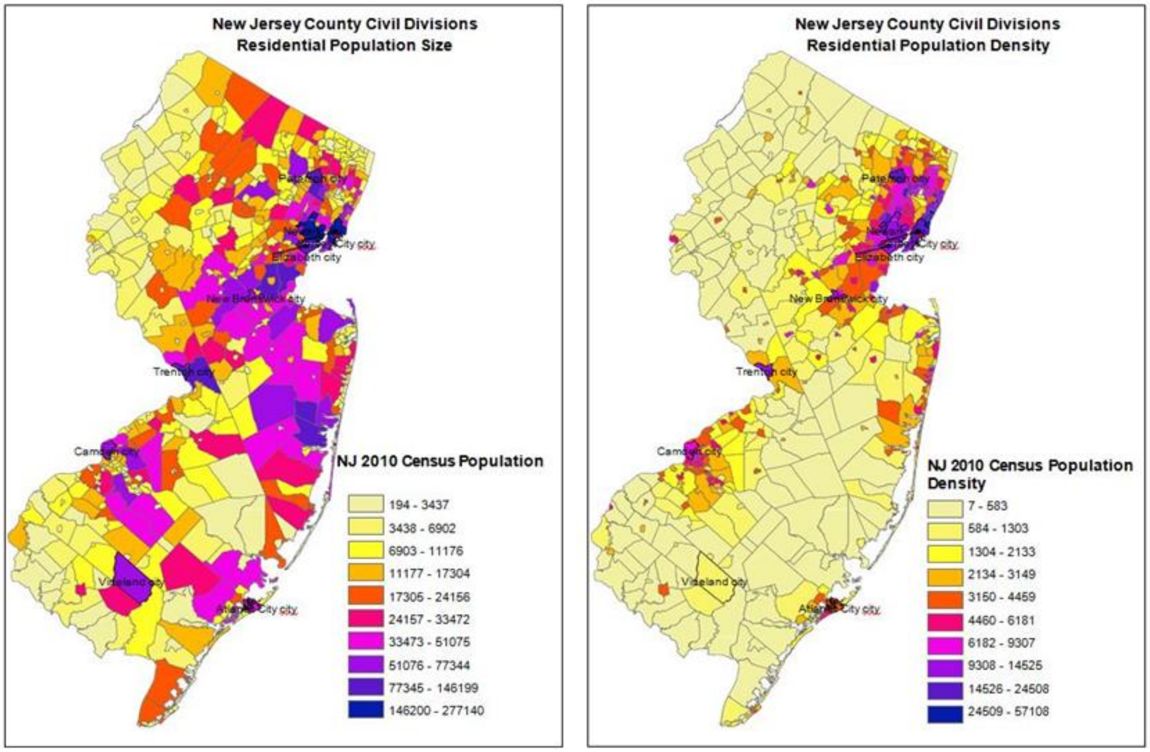

Figure 3: New Jersey Residential Population Size and Density by County Civil Division Based on 2010 Census
Adapted from the U. S. Census Bureau. (2011, May 26). The United States 2010 Census. Retrieved from https://www2.census.gov/census_2010/03-demographic_profile/New_Jersey.

As noted with population variables of size and density, neighborhood SED was very heterogeneous among the 566 CCDs, reflective of towns with substantial poverty as well as considerable affluence. Figure 4 illustrates that the metropolitan areas of New York, Philadelphia, Trenton, and Atlantic City have high levels of SED as measured by TSI. This finding further exemplifies the disparate distribution of wealth and poverty within these large urban cities. Additionally, Figure 4 demonstrates that while higher measures of SED associated with NCD are observed in similar metropolitan areas as noted with TSI, there appears to be a more dispersed pattern of higher SED in the central and southern half of the state, which is also noted to be more rural.

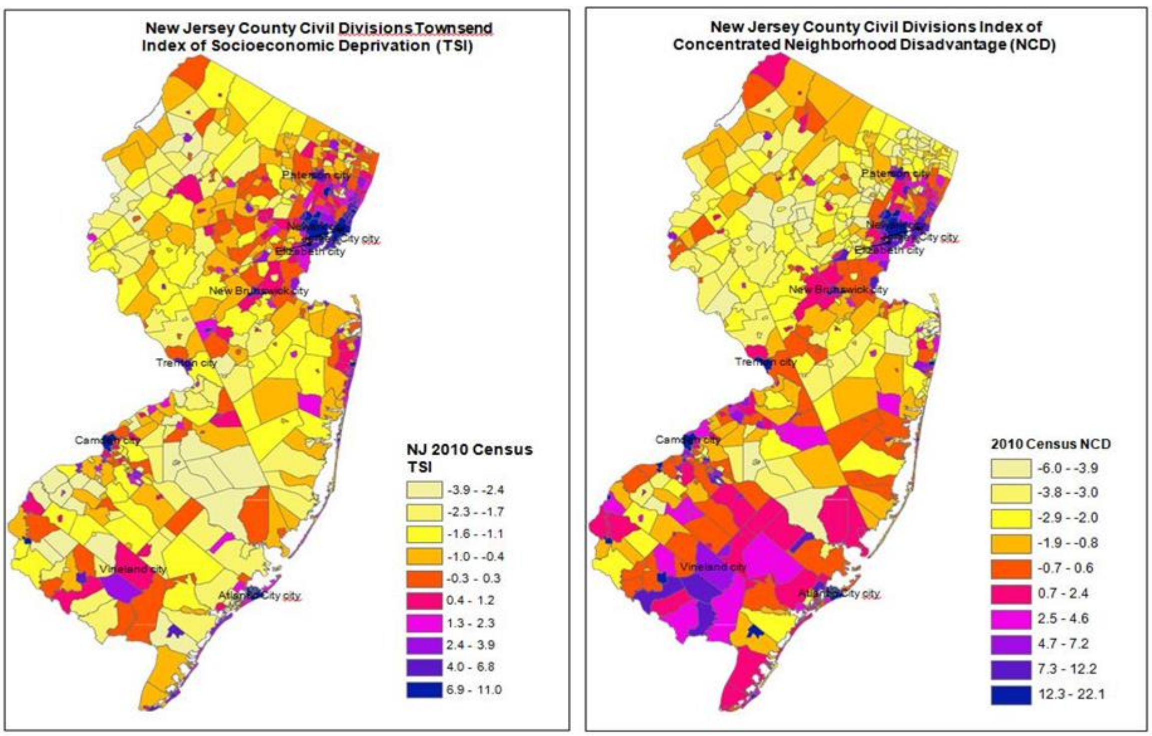

Figure 4: New Jersey Index of Socioeconomic Deprivation as Measured by the Townsend Index and Index of Concentrated Neighborhood Disadvantage by County Civil Division
Adapted from the U. S. Census Bureau. (2011, May 26). The United States 2010 Census. Retrieved from https://www2.census.gov/census_2010/03-demographic_profile/New_Jersey.

Lastly, demonstrated in Table 5 is the wide variation in both deprivation indices and their component variables across municipalities. Of significance is the disparity noted among the component variables; percent of single parents with dependents, percent of household rental, and percent minority.

4.3 Descriptive Statistics of Study Population: Dependent Variable

Descriptive statistics used to estimate the age-specific incidence of fall-related injury within New Jersey's 566 CCDs showed considerable variation with respect to subacute and acute fall-related injury rates. Specifically, there was an 186.8% difference between the rate of subacute fall injuries for municipalities at the 5^{th} and 95^{th} confidence intervals for both genders and all age groups. Furthermore, there was an 181.0% difference between the rate of acute fall injuries for CCDs at the 5^{th} and 95^{th} confidence intervals among males and females, as well as all age cohorts combined.

Displayed in Figure 5 is a heat map of subacute fall-related injury rates as compared with acute fall-related injury rates for the 566 County Civil Divisions within the state of New Jersey. Both subacute and acute fall injury rates were noted to have a similar geographic distribution pattern within the state. Additionally, fall-related injury rates were observed to be higher in the coastal and metropolitan areas of the state.

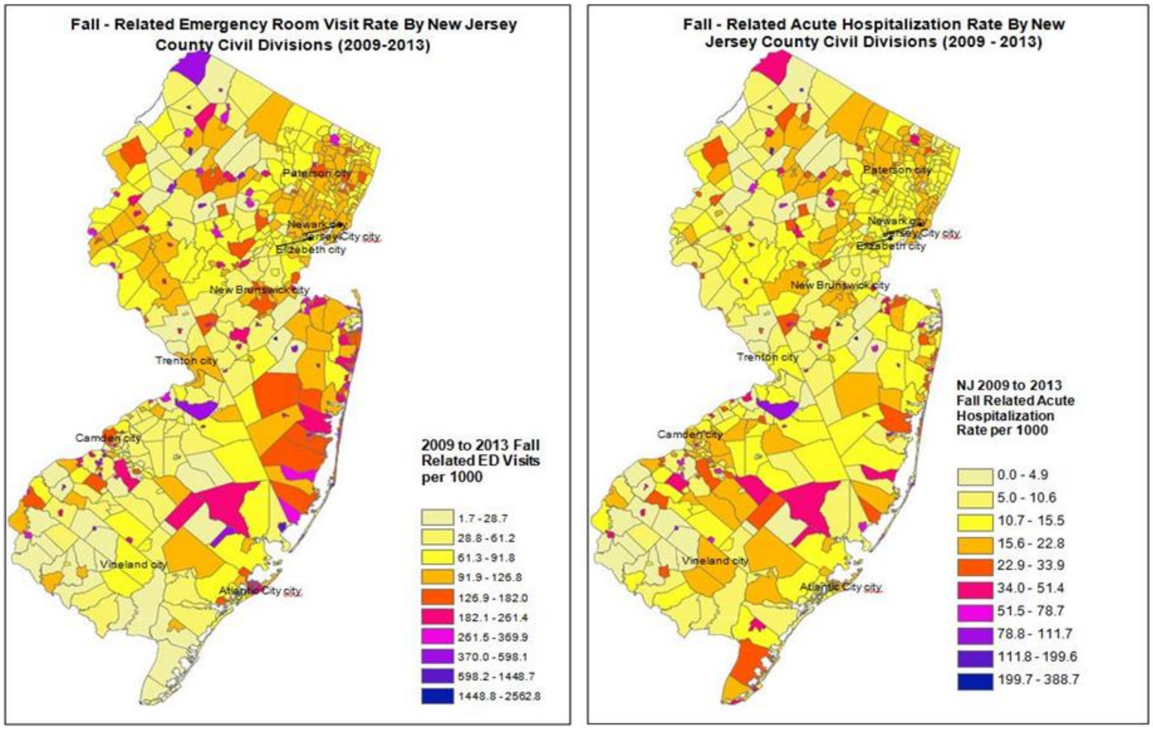

Figure 5: New Jersey Fall-Related Emergency Department Visit Rate and Acute Hospitalization Rate by County Civil Division
Adapted from the U. S. Census Bureau. (2011, May 26). The United States 2010 Census. Retrieved from https://www2.census.gov/census_2010/03-demographic_profile/New_Jersey.

Provided in Table 6 is a geographic summary of subacute and acute fall-related injury rates by county within New Jersey. Observations reveal higher subacute fall-related injury rates in central Ocean and Monmouth shore counties, as well as the northern county of Sussex. Additionally, subacute fall injury rates are noted to be high in Gloucester and Salem Counties in the southern section of the state, and Sussex, Hunterdon, and Morris Counties in the northwestern section of the state.

Table 6: Geographic Representation of Subacute and Acute Fall-Related Injury Rates by New Jersey County for Years 2009-2013

SUBACUTE AND ACUTE FALL INJURY RATES AMOUNG NEW JERSEY COUNTIES							
New Jersey County	Subacute Fall-Related Injury Rate	95th Percentile Upper Limit Of Mean	95th Percentile Lower Limit Of Mean		Acute Fall-Related Injury Rate	95th Percentile Upper Limit Of Mean	95th Percentile Lower Limit Of Mean
Atlantic County	108.7	143.8	73.6		14.1	18.1	10.2
Bergen County	98.0	105.3	90.8		15.3	16.4	14.2
Burlington County	86.2	115.1	57.4		19.1	25.0	13.3
Camden County	75.2	95.5	55.0		20.0	24.9	15.0
Cape May County	54.2	108.1	0.3		20.8	27.0	14.6
Cumberland County	45.8	66.5	25.0		10.1	15.0	5.2
Essex County	103.0	113.5	92.4		14.1	16.0	12.1
Gloucester County	141.6	195.6	87.5		22.6	29.7	15.5
Hudson County	98.0	109.9	86.1		15.7	17.6	13.8
Hunterdon County	147.4	183.6	111.2		18.6	23.5	13.6
Mercer County	98.8	137.5	60.0		16.1	22.9	9.2
Middlesex County	122.1	166.8	77.3		22.6	37.3	7.8
Monmouth County	235.0	335.7	134.2		29.6	44.2	15.0
Morris County	120.9	153.8	88.0		17.4	21.5	13.3
Ocean County	280.2	428.2	132.2		30.9	50.1	11.7
Passaic County	101.5	118.0	84.9		15.6	18.4	12.9
Salem County	112.5	179.6	45.4		18.5	33.1	3.8
Somerset County	91.8	117.7	65.9		17.1	20.9	13.4
Sussex County	240.3	372.3	108.4		30.1	45.4	14.8
Union County	78.3	87.3	69.4		12.8	14.2	11.5
Warren County	128.8	176.4	81.3		14.8	20.0	9.5
Total	130.9	146.9	115.0		19.7	21.9	17.4

* Rates reflect the number of subacute and acute fall-related injury from 2009-2013, per thousand (RPK) New Jersey residents

Subacute fall-related injury.

Shown in Table 7 are the age and gender-specific incidence rates of subacute fall-related injury during 2009-2013 for residents of New Jersey. In line with nationally reported statistics, the number of subacute fall-related injuries exceeded the number of acute fall-related injuries, for both males and females across all age groups.

Table 7: Subacute, Emergency Department Visit Fall-Related Injury Rates for Residents of New Jersey During 2009-2013

FALL-RELATED EMERGENCY DEPARTMENT (ED) VISITS PER 1,000 RESIDENTS (RPK) BY GENDER AND AGE COHORT IN NEW JERSEY FOR 2009-2013				
VARIABLES:	Mean	Std. Error of Mean	5th Percentile	95th Percentile
ED Visit RPK for All Male and Females	129.01	8.83	12.29	361.26
ED Visit RPK for Males 0-14 Years	229.16	16.05	10.24	608.13
ED Visit RPK for Males 15-24 Years	114.83	7.08	4.60	332.22
ED Visit RPK for Males 25-44 Years	73.10	4.79	6.70	203.46
ED Visit RPK Males 45-64 Years	72.28	5.06	5.33	204.82
ED Visit RPK Males 65-84 Years	134.91	10.74	6.59	352.94
ED Visit RPK Males > 85 Years	425.93	37.82	0.00	1180.30
ED Visit RPK for All Males	115.65	6.74	11.17	328.97
ED Visit RPK Females 0-14 Years	172.65	10.46	7.61	456.11
ED Visit RPK Females 15-24 Years	101.63	8.18	6.43	299.80
ED Visit RPK Females 25-44 Years	102.50	17.58	4.55	252.51
ED Visit RPK Females 45-64 Years	111.65	7.22	10.49	315.27
ED Visit RPK Females 65-84 Years	212.64	15.07	17.28	595.18
ED Visit RPK Females > 85 Years	540.23	50.05	14.39	1342.08
ED Visit RPK for All Females	147.25	15.37	13.52	385.39

Figure 3 illustrates a bi-modal or U-shaped distribution of ED fall-related injuries with respect to males. The number of visits for subacute injuries was highest in the two youngest cohorts, 0-14 years as well as 15-24 years, and in the two oldest age groups, 65-84 years as well as 85 years and older. Compared to males, the pattern of ED fall-related injuries differed for females as injury rates progressively increased from the youngest to the oldest age cohort, excluding the youngest age group 0-14 years. In all age cohorts except the youngest, 0-14 years and 15-24 years, ED fall-related injuries were higher for females.

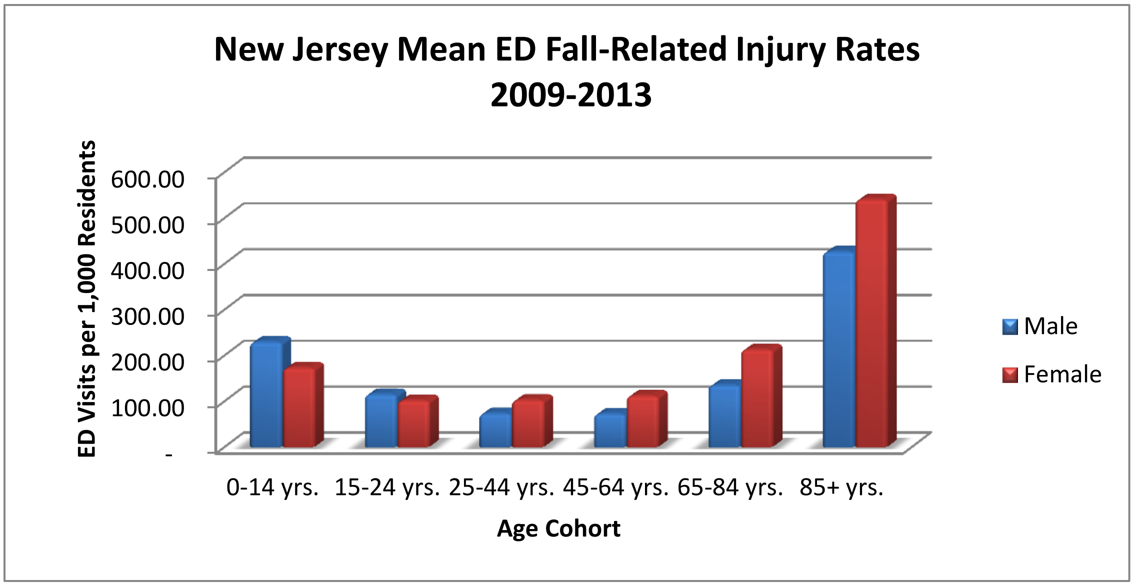

Figure 6: Subacute Emergency Department Fall-Related Injury Visit Rates by Age and Gender

Acute fall-related injury.

Displayed in Table 8 is the incidence of acute fall-related injury during 2009-2013 for residents of New Jersey by gender and age cohorts. Analysis of acute fall-related injuries within New Jersey's 566 municipalities indicated slightly more hospital fall-related injuries for younger males than females in age groups 0-14 years as well as 15-24 years. Acute fall rates were similar for males and females in age cohorts 25-44 years and 45-65 years. However, hospital fall-related injuries were highest in the female age cohorts 65-84 years and 85 years and older. Shown in Figure 4 are acute fall-related injury rates by age and gender groupings. Acute fall-related injury revealed a J-shaped distribution as opposed to the U-shape distribution associated with subacute fall injury

Table 8: Acute, Hospital Stay Fall-Related Injury Rates for Residents of New Jersey During 2009-2013

FALL-RELATED HOSPITAL STAYS PER 1,000 RESIDENTS (RPK) BY GENDER AND AGE COHORT IN NEW JERSEY FOR 2009-2013				
VARIABLES:	Mean	Std. Error of Mean	5th Percentile	95th Percentile
Hospital Stay RPK for All Male and Females	20.5773	1.36798	2.7415	54.4745
Hospital Stay RPK for Males 0-14 Years	7.2201	.95700	.0000	20.1655
Hospital Stay RPK for Males 15-24 Years	7.5954	.46216	.0000	25.5975
Hospital Stay RPK for Males 25-44 Years	6.8130	.64565	.0000	18.7311
Hospital Stay RPK Males 45-64 Years	14.4330	1.86414	.0001	37.3959
Hospital Stay RPK Males 65-84 Years	43.8672	3.00224	.0004	127.0658
Hospital Stay RPK Males ≥ 85 Years	200.4504	15.70360	.0005	551.2690
Hospital Stay RPK for All Males	15.8134	1.02177	1.3741	41.4889
Hospital Stay RPK Females 0-14 Years	4.2877	.39006	.0000	13.2469
Hospital Stay RPK Females 15-24 Years	3.1010	.24127	.0000	11.4943
Hospital Stay RPK Females 25-44 Years	6.0767	1.78635	.0000	13.1593
Hospital Stay RPK Females 45-64 Years	14.6596	1.10163	.0020	37.4859
Hospital Stay RPK Females 65-84 Years	74.0405	4.68091	8.0916	179.5949
Hospital Stay RPK Females ≥ 85 Years	299.4386	20.30612	13.9614	794.5458
Hospital Stay RPK for All Females	25.7825	2.22629	2.5954	65.3765

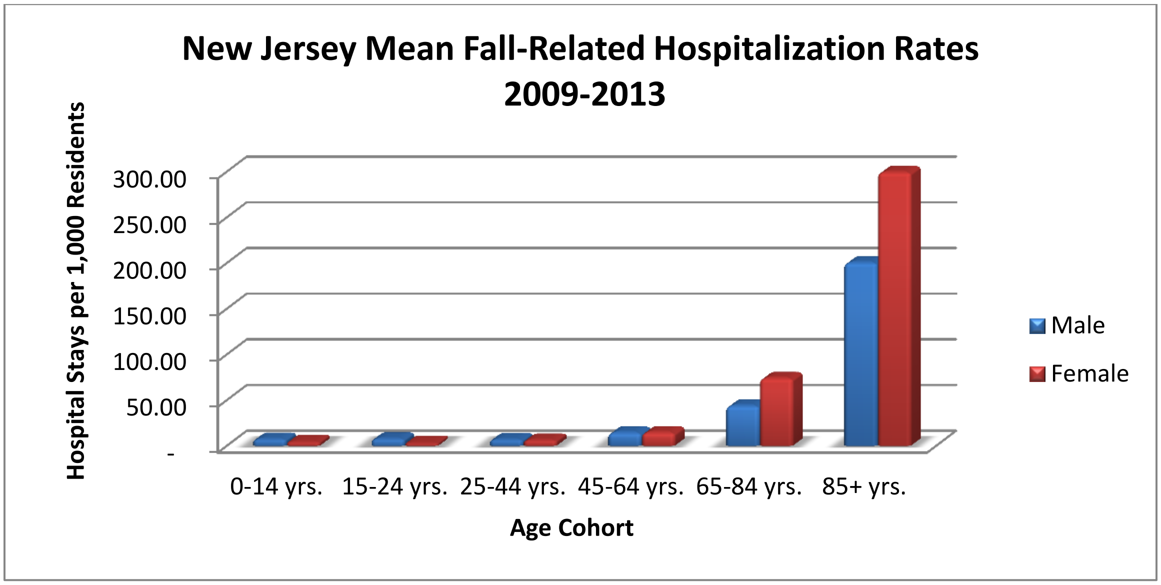

Figure 7: Acute Hospital Stay Fall-Related Injury Rates by Age and Gender

4.4 Inferential Statistics: Correlation Among Variables

Statistical procedures to assess the correlation, or potential for confounding, among study independent variables demonstrated that population size, population density, and SED were significantly inter-related with coefficients ranging from 0.3 versus 0.8, and all coefficients significant at the 0.01 level. Moreover, consistent with the literature regarding SED measures, TSI and NCD were strongly correlated, with their respective composite variables ranging from 0.7-0.9. Table 9 illustrates the inter-relationship among the ecological variables and individual components of SED measures.

Table 9: Correlation Among Study Independent Variables

CORRELATION AMONG INDEPENDENT VARIABLES BASED ON COUNTY CIVIL DIVISION 2010 CENSUS AND AMERICAN COMMUNITY SURVEY DATA				
INDEPENDENT VARIABLES:	Neighborhood Concentrated Disadvantages	Townsend Index	Population Size	Population Density
Population Size	0.324**	0.344**	1	0.315**
Population Density	0.394**	0.597**	0.315**	1
% Population Below Federal Poverty Level	0.869**	0.689**	0.299**	0.386**
% Dependent Single Parent	0.905**	0.652**	0.213**	0.352**
% Public Assistance	0.829**	0.491**	0.203**	0.171**
% Household Below Federal Poverty Level	0.895**	0.717**	0.306**	0.417**
% Household Rental	0.674**	0.804**	0.315**	0.589**
% No Car	0.748**	0.873**	0.443**	0.703**
% Unemployed	0.767**	0.590**	0.146**	0.144**
% Minority	0.717**	0.613**	0.472**	0.544**
**Correlation is significant at the 0.01 level (2-tailed).				

4.5 Inferential Statistics: Linear Regression

Linear regression models with robust standard errors were employed to assess variation in subacute and acute fall-related injury rates by the level of population size, density, and SED for each gender and age cohort (see Appendices B through E for complete result tables associated with subacute linear regression models, and Appendices F through I for complete result tables associated with acute linear regression models).

Subacute fall-related injury; impact of population size.

Regression coefficients associated with residential population size were shown to have a negative direction of correlation to subacute fall-related injury. While coefficients were statistically significant in all male age cohorts irrespective of SED measure, the observed size of the effect was relatively small. Similarly, the direction of correlation of population size to subacute all-related injury was found to be negative for all female age cohorts. Also, though regression coefficients were statistically significant across all female age groupings, the size of the effect was negligible.

Subacute fall-related injury; impact of population density.

Regression coefficients related to residential population density were demonstrated to have a negative direction of correlation to subacute fall-related injury. Associated coefficients were not statistically significant across all male age groupings, and the size of the effect was insignificant irrespective of SED measure. Like observations were associated with female age cohorts as population density was negatively correlated with subacute fall-related injury. Additionally, regression coefficients were not statistically significant, and the size of effect marginal.

Shown in the following tables is the combined net impact of population size and population density on the average subacute fall-related injury rate relative to gender and age group. Of note, the combined net impact is demonstrated using a baseline representing a fixed unit of measure, or rate per thousand (RPK) residents. Table 10 represents findings which used NCD to measure SED, while Table 11 depicts results associated with the TSI.

Table 10: Effect of Population Size and Population Density on Subacute, Emergency Department Visit Fall-Related Injury Rates Among Female and Male Age Cohorts when Neighborhood Concentrated Disadvantage was used to Measure Socioeconomic Deprivation

Combined Net Effect of Population Size and Density on Subacute Fall-Related Injury Rates (RPK) when Neighborhood Concentrated Disadvantage Index used to Measure Socioeconomic Deprivation												
	0-14 Years		15-24 Years		25-44 Years		45-64 Years		65-84 Years		≥ 85 Years	
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
Intercept; baseline/average RPK	191.50	251.50	119.90	132.70	104.80	82.30	121.00	77.41	236.60	151.90	625.90	486.70
Population Size RPK ***p<0.01 **p<0.05	190.18**	249.77**	118.93**	131.71**	104.01**	81.74***	120.17**	76.94**	234.90**	150.76**	621.31**	482.96**
Population Density RPK ***p<0.01 **p<0.05	192.09	252.97	119.07	131.78	103.25	81.43	120.85	77.15	237.23	152.30	622.07	486.30

Table 11: Effect of Population Size and Population Density on Subacute, Emergency Department Visit Fall-Related Injury Rates Among Female and Male Age Cohorts when Townsend Index was used to Measure Socioeconomic Deprivation

Combined Net Effect of Population Size and Density on Subacute Fall-Related Injury Rates (RPK) when Townsend Index used to Measure Socioeconomic Deprivation												
	0-14 Years		15-24 Years		25-44 Years		45-64 Years		65-84 Years		≥ 85 Years	
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
Intercept; baseline/average RPK	209.90	282.70	134.40	143.60	115.90	88.58	130.10	82.60	248.70	159.20	664.50	509.10
Population Size RPK ***p<0.01 **p<0.05	208.35**	280.52**	133.24***	144.48***	115.02**	87.98***	129.15**	82.11**	246.90**	158.01**	659.43**	505.13**
Population Density RPK ***p<0.01 **p<0.05	206.14	277.08	130.18	140.08**	111.48	86.03	127.47	80.85	246.29	157.69	651.58	503.20

Subacute fall-related injury; impact of socioeconomic deprivation.

The following discussion related to the impact of SED on the fall-related injury used coefficients associated with county civil divisions (CCDs) at the 5th and 95th confidence intervals of NCD and TSI measures, as shown in Table 5, to predict the effect of low and high SED on the average injury rate. Displayed in the tables below is the observed net effect of SED on subacute fall-related injury rates using a baseline representing a fixed unit of measure (rate per thousand (RPK) residents; Table 12 illustrates the predicted fall injury rate for CCDs at the 5th and 95th confidence intervals with NCD as the SED measure, and Table 13 shows the predicted effect of high and low SED with TSI.

Socioeconomic measure; Neighborhood Concentrated Disadvantage Index.

Regression coefficients were statistically significant in the 25-44 and 45-64 male age cohorts with NCD as the measure for SED. Low SED predicted the intercept coefficient, or average rate, in the 25-44 male age cohort to decrease by 19%. Conversely, high SED predicted that average to increase by 39%. This effect was similar in the 45-64 male age cohort, whereby low SED predicted the average fall rate to decrease by 24%, and high SED predicted an increase in that average by 50%.

Comparable to findings in males, when NCD was used to measure SED in females, regression coefficients were statistically significant in the 25-44 and 45-64 age cohorts. Low SED predicted a decrease of 21% in the average rate of subacute injury in the 25-44 female age group, while high SED predicted an increase of 43%. A similar effect was also observed in the 45-64 female age group, as low SED predicted a decrease in the average fall injury rate of 22% and high SED predicted an increase of 46%.

Socioeconomic measure; Townsend Index.

Regression models demonstrated that TSI was a more discriminant measure of SED than NCD. Coefficients were statistically significant in all male age groups except for the ≥ 85 age cohort. Coefficients with the strongest statistical significance, meeting the test of 0.01, were associated with the 25-44 and 45-64 age cohorts. In the 25-44 male age cohort, low SED projected a decrease in the average injury rate by 33%, whereas high SED projected an increase of 61%. Like results was noted in the 45-64 male age cohort, as low SED projected a decrease in the average injury rate by 35%, and high SED increased the average by 65%.

Regression coefficients associated with TSI were statistically significant across all female age cohorts except the ≥ 85 grouping. Coefficients with the strongest statistical significance, meeting the test of 0.01, were observed in the 45-64 female age cohort. Also, the size of the effect was found to be larger with TSI as the measure for SED versus NCD. Low SED predicted a decrease in the average injury rate in the 45-64 female age group by 35%. Conversely, the impact of high SED predicted an increase in the average injury rate by 66%.

Table 12: Effect of High and Low Socioeconomic Deprivation as Measured by the Neighborhood Concentrated Disadvantage Index on Subacute Fall-Related Injury Rates Among Female and Male Age Cohorts

Effect of Socioeconomic Deprivation (SED) as Measured by Neighborhood Concentrated Disadvantage Index (NCD) on Subacute Fall-Related Injury [Rate per Thousand (RPK)]												
	0-14 Years		15-24 Years		25-44 Years		45-64 Years		65-84 Years		≥ 85 Years	
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
Intercept; baseline/ average RPK	191.50	251.50	119.90	132.70	104.80	82.30	121.00	77.42	236.60	151.90	625.90	486.70
RPK with Low SED; NCD at the 5th CI (-4.05) ***p<0.01 **p<0.05	178.07	245.19	110.98	123.61	82.99**	66.64**	94.06***	58.87***	216.57	136.05	598.59	455.48
RPK with High SED; NCD at the 95th CI (8.4) ***p<0.01 **p<0.05	219.33	264.57	138.38	151.54	150.02**	114.76**	176.86***	115.87***	278.13	184.76	682.53	548.92

Table 13: Effect of High and Low Socioeconomic Deprivation as Measured by the Townsend Index on Subacute Fall-Related Injury Rates Among Female and Male Age Cohorts

Effect of Socioeconomic Deprivation (SED) as Measured by Townsend Index (TSI) on Subacute Fall-Related Injury [Rate per Thousand (RPK)]												
	0-14 Years		15-24 Years		25-44 Years		45-64 Years		65-84 Years		≥ 85 Years	
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
Intercept; baseline/average RPK	209.90	282.70	134.40	143.60	115.90	88.58	130.10	82.60	248.7	159.20	664.50	509.10
RPK with Low SED; TSI at the 5th CI (-2.6) ***p<0.01 **p<0.05	152.57**	199.99**	90.74**	108.57**	69.02**	59.22***	83.92***	53.40***	201.22**	127.09***	545.08	427.90***
RPK with High SED; TSI at the 95th CI (4.8) ***p<0.01 **p<0.05	315.74**	435.38**	214.99**	208.25**	202.44**	142.77***	201.14***	136.50***	336.44**	218.48***	884.96	659.00***

Acute fall-related injury; impact of population size.

Regression coefficients associated with residential population size were shown to have a negative correlation to acute fall-related injury. Coefficients associated with the regression model using TSI to measure SED were statistically significant in all male age cohorts. Regression coefficients related to the model using NCD to measure SED were noted to be statistically relevant in all age groupings except for the 0-14 age cohort. However, regardless of SED measure, the size of the effect was noted to be minimal across all age groups.

Results assessing the relationship between population size and acute fall-related injury rates in female cohorts were similar to those associated with males. The direction of correlation of population size to acute fall-related injury was negative. Coefficients associated with the regression model using TSI to measure SED were statistically significant across all female age groupings. Regression coefficients associated with the model using NCD to measure SED were statistically significant in all female age cohorts except the 0-14 age group. Additionally, irrespective of SED measure, regression models demonstrated that the size of the effect was relatively insignificant.

Acute fall-related injury; impact of population density.

The direction of correlation of residential population density to acute fall injury in the model using TSI to measure SED was negative in the 15-24, 25-44, and 45-64 age groups, and positive in the 0-14 and ≥ 85 age cohorts. However, the direction of correlation in the regression model using NCD as a measure for SED was negative in all age groups. Population density coefficients associated with the regression model using TSI to measure SED were statistically significant in the 25-44 and 45-64 age groupings. Regression coefficients related to the model employing NCD to measure SED only met the test of critical significance in the 25-44 age cohort. Regardless of SED measure, associated coefficients were noted to have a small size effect.

The direction of correlation of population density to acute fall-related injury was negative in all female age groups except the 0-14 age cohort in the model using NCD to measure SED. Population density coefficients in the regression model using TSI as a measure for SED females were statistically significant in the 25-44, 45-64, and 65-84 age groups. Population density coefficients did not meet the critical test of statistical significance with NCD as the measure for SED. In both regression models, population density had a marginal size effect on acute fall-related injury rates.

Shown in the following tables is the combined net impact of population size and population density on the average acute fall-related injury rate relative to gender and age groupings. Of note, the combined net impact is demonstrated using a baseline representing a fixed unit, or rate per thousand (RPK) residents. Table 14 represents findings associated with regression models which used NCD to measure SED, and Table 15 depicts results linked to regression models using TSI.

Table 14: Effect of Population Size and Population Density on Acute, Hospital Stay Fall-Related Injury Rates Among Female and Male Age Cohorts when Neighborhood Concentrated Disadvantage was used to Measure Socioeconomic Deprivation

Combined Net Effect of Population Size and Density on Acute Fall-Related Injury Rates (RPK) when Neighborhood Concentrated Disadvantage Index used to Measure Socioeconomic Deprivation												
	0-14 Years		15-24 Years		25-44 Years		45-64 Years		65-84 Years		≥ 85 Years	
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
Intercept; baseline/average RPK	4.70	7.94	3.57	8.65	5.17	8.08	16.18	14.86	84.36	49.44	341.50	228.00
Population Size RPK ***p<0.01 **p<0.05	4.66	7.87	3.54**	8.58**	5.13***	8.03**	16.05***	14.75***	83.70***	49.06**	339.05***	226.24***
Population Density RPK ***p<0.01 **p<0.05	4.72	8.02	3.56	8.63	5.11	7.96**	16.05	14.72	84.29	49.57	340.54	228.07

Table 15: Effect of Population Size and Population Density on Acute, Hospital Stay Fall-Related Injury Rates Among Female and Male Age Cohorts when Townsend Index was used to Measure Socioeconomic Deprivation

Combined Net Effect of Population Size and Density on Acute Fall-Related Injury Rates (RPK) when Townsend Index used to Measure Socioeconomic Deprivation												
	0-14 Years		15-24 Years		25-44 Years		45-64 Years		65-84 Years		≥ 85 Years	
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
Intercept; baseline/average RPK	5.07	9.67	3.78	9.13	5.70	9.16	17.01	16.16	88.51	52.02	360.30	241.50
Population Size RPK *** p<0.01 ** 0<0.05	5.03**	8.76**	3.75***	9.06***	5.66***	9.10***	16.88***	16.04***	87.83***	51.63***	357.64***	239.61***
Population Density RPK *** p<0.01 ** 0<0.05	5.01	9.37	3.71***	8.99	5.50***	8.77**	16.63**	15.67***	87.34	51.47	354.77	238.28

Acute fall-related injury; impact of socioeconomic deprivation.

The following discussion regarding the impact of SED on acute fall-related injury takes a like approach to the subacute injury analysis. The SED coefficients linked with county civil divisions (CCDs) at the 5^{th} and 95^{th} confidence intervals, as shown in Table 5, were used to predict the impact of low and high SED on the average injury rate. Demonstrated in the following tables is the observed effect of SED on acute, hospital stay fall-related injury rates among gender and age cohorts. Table 16 reflects the predicted fall injury rate for CCDs at the 5^{th} and 95^{th} confidence intervals when NCD is used to measure SED, and Table 17 shows the predicted effect of high and low SED with TSI.

Socioeconomic measure; Neighborhood Concentrated Disadvantage Index.

Regression coefficients associated with the NCD model were statistically significant in the 25-44, 45-64, and 65-84 male age groupings. High SED predicted an increase in the average acute fall-related injury rate in the 25-44 male age cohort by 45%. Conversely, low SED predicted that average to decrease by 22%. This effect was similar in the remaining two male age grouping. High SED projected the average acute fall injury rate would increase by 52%, and low SED would decrease that average by 25% for males in the 45-65 grouping. Lastly, in the 65-84 age cohort, high SED projected an increase in the average acute fall rate by 25%, and low SED projected a 12% decrease in that average rate.

Similar to findings associated with males, when NCD was used to measure SED in females, coefficients were statistically significant in the 25-44, 45-64 and 65-84 age cohorts. High SED predicted an increase in the average injury rate of 51% in the 25-44 female age cohort. Conversely, low SED predicted that average to decrease by 25%. Also evident in the 45-64 and 65-84 age groupings respectively, was a predicted increase in the average fall injury rate of 44% and 25% with high SED, and a predicted decrease in that average by 21% and 12% with low SED.

Socioeconomic measure; Townsend Index.

Regression models demonstrated that TSI had a stronger association with acute fall-related injury when compared to NCD when used to measure SED. Coefficients were statistically significant in all male age groups. In the 25-44 male age cohort, high SED projected an increase of 85% in the average acute injury rate, where low SED projected a decrease of 46%. Like results were noted in the remaining three male age cohorts; high SED projected an increase in the average acute injury rate by 74% in the 45-64 age grouping, 41% in the 65-84 age grouping, and 37% in the >85 age grouping.

Conversely, low SED projected a decrease in that average by 40 % in the 45-64 age grouping, 22% in the 65-84 age grouping, and 20% in the ≥ 85 age grouping.

Regression coefficients in the model using TSI to measure SED were statistically significant in all age cohorts except the two youngest groups, those 0-14 and 15-24 years. High SED predicted an increase in the average injury rate in the 25-44 age group of 79%, and conversely, low SED predicted a decrease in that average of 42%. Observed was a similar impact in the remaining female age cohorts. High SED predicted an increase in the average injury rate in the 45-64, 65-84, and ≥ 85 age groupings of 56%, 40%, and 33%, and low SED predicted a decrease of 30%, 22%, and 18% respectively.

Table 16: Effect of High and Low Socioeconomic Deprivation as Measured by the Neighborhood Concentrated Disadvantage Index on Acute, Hospital Stay Fall-Related Injury Rates Among Female and Male Age Cohorts

Effect of Socioeconomic Deprivation (SED) as Measured by Neighborhood Concentrated Disadvantage Index (NCD) on Acute Fall-Related Injury [Rate per Thousand (RPK)]												
	0-14 Years		15-24 Years		25-44 Years		45-64 Years		65-84 Years		≥ 85 Years	
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
Intercept; baseline/average RPK	4.70	7.94	3.57	8.65	5.17	8.08	16.18	14.86	84.36	49.44	341.50	228.00
RPK with Low SED; NCD at the 5th CI (-4.05) *** p<0.01 ** 0<0.05	4.54	6.97	3.25	8.16	3.89***	6.31***	12.72***	11.15***	74.04***	43.49***	321.14	210.14
RPK with High SED; NCD at the 95th CI (8.4) *** p<0.01 ** 0<0.05	5.01	8.14	4.23	9.65	7.81	11.75	23.34	22.53	105.76	61.77	383.71	265.02

Table 17: Effect of High and Low Socioeconomic Deprivation as Measured by the Townsend Index on Acute, Hospital Stay Fall-Related Injury Rates Among Female and Male Age Cohorts

Effect of Socioeconomic Deprivation (SED) as Measured by Townsend Index (TSI) on Acute Fall-Related Injury [Rate per Thousand (RPK)]												
	0-14 Years		15-24 Years		25-44 Years		45-64 Years		65-84 Years		≥ 85 Years	
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
Intercept; baseline/average RPK	5.07	9.67	3.78	9.13	5.70	9.16	17.01	16.16	88.51	52.02	360.30	241.50
RPK with Low SED; TSI at the 5th CI (-2.6) *** p<0.01 ** 0<0.05	4.01	5.41**	2.98	7.49**	8.13***	4.93***	11.89***	9.69***	69.14***	40.38***	295.63***	192.85***
RPK with High SED; TSI at the 95th CI (4.8) *** p<0.01 ** 0<0.05	7.00	17.41**	5.23	12.14**	10.19***	16.36***	26.45***	28.10***	124.27***	73.50***	479.58***	331.30***

Acute fall-related injury; combined effects of population size and socioeconomic deprivation on acute fall-related injury rates among age and gender cohorts.

The subsequent discussion maintains a focus on acute injury data as these patterns reflected a similarity to subacute injury, and because of the associated degree of injury severity and overarching impact on public health. Additionally, evaluation of the impact of ecologic covariates centers on population size and SED as measured by TSI because they were demonstrated to have the strongest statistical association with acute fall injury. Moreover, the analysis focuses on the population quartile approach to modeling population size rather than models which evaluate a single, or linear, population size effect on acute fall-related injury.

In this discussion, the emphasis is on particular patterns in the size of effects of the covariates on acute injury rates. It is useful to make some relative comparisons of the combined effects of SED with higher, median, and lower quartiles of population size. Such an assessment can be accomplished by comparing towns with low SED at various population size levels and to show these comparisons for different age and gender cohorts.

In using population and SED quartiles, in was noted that injury rates decreased from the lower to higher population quartiles, irrespective of gender, age, or measure of SED. Additionally, the largest percent increase in acute fall-related injury rate had a positive association with higher SED and population quartiles in the 0-14, 25-44, and 45-64 male age groupings, and in the 25-44 and 45-64 female age groupings. Furthermore, these male and female age groupings consistently had the largest percent increase in injury rate associated with high SED in all three population quartiles. Table 18 displays quartile data associated with acute fall-related injury rates, adjusting for age, gender, population size, and SED.

Table 18: Predicted Acute Fall-Related Injury Rates Adjusted for Age and Gender Using Population and Socioeconomic Deprivation Quartiles

ACUTE FALL-RELATED INJURY RATES* (RPK) ADJUSTING FOR AGE, GENDER, POPULATION SIZE AND SOCIOECONOMIC DEPRIVATION (SED) AS MEASURED BY THE TOWNSEND INDEX (TSI)*						
	FEMALES			MALES		
LOWER & UPPER QUARTILES OF TSI	SIZE OF RESIDENTIAL POPULATION AMONG NJ TOWNS (N=562)					
LOW SED	LOWER QUARTILE	MEDIAN	HIGHER QUARTILE	LOWER QUARTILE	MEDIAN	HIGHER QUARTILE
RPK 0-14 Years	**3.7**	**3.5**	**3.2**	**4.3**	**3.9**	**3.0**
RPK 15-24 Years	**2.7**	**2.6**	**2.3**	**6.9**	**6.6**	**5.9**
RPK 25-44 Years	**2.6**	**2.4**	**1.9**	**3.7**	**3.4**	**2.8**
RPK 45-64 Years	**10.4**	**9.9**	**8.7**	**7.9**	**7.4**	**6.3**
RPK 65-84 Years	**63.2**	**60.2**	**53.5**	**37.2**	**35.5**	**31.6**
RPK ≥85 Years	**270.8**	**259.2**	**232.5**	**176.6**	**168.4**	**149.4**
HIGH SED						
RPK 0-14 Years	**5.4**	**5.2**	**4.8**	**10.9**	**10.5**	**9.6**
RPK 15-24 Years	**4.0**	**3.8**	**3.5**	**9.5**	**9.2**	**8.5**
RPK 25-44 Years	**6.4**	**6.2**	**5.8**	**10.4**	**10.1**	**9.5**
RPK 45-64 Years	**18.5**	**18.0**	**16.7**	**18.2**	**17.7**	**16.5**
RPK 65-84 Years	**93.8**	**90.9**	**84.1**	**55.6**	**53.9**	**50.0**
RPK ≥85 Years	**373.0**	**361.4**	**334.6**	**253.5**	**245.3**	**226.3**

*Rates reflect the number of fall-related acute hospitalizations, from 2009 through 2013, per thousand NJ residents per age/sex cohort after adjustment for population density, population size, and level of socioeconomic deprivation as measured by the Townsend Index, as predicted by multivariable regression analysis with robust standard errors.

By establishing average acute injury rates for the respective groups of towns with higher and lower SED at higher, median, and lower levels of population size, rate ratios were computed to compare acute fall-related injury rates among higher SED towns as a ratio of the rates among lower SED towns. As shown in Table 19, these rate ratios suggest higher SED has a positive association with higher acute injury rates as compared with lower SED, and this effect remained consistent across different population size towns. However, this SED effect appeared stronger for young and middle-aged males, in contrast with their female counterparts.

Table 19: Combined Net Effects of Population Size and Socioeconomic Deprivation on Acute Fall-Related Injury Rates Among Gender and Age Cohorts; Rate Ratios of Higher Socioeconomic Deprivation

RATIO OF ACUTE FALL-RELATED INJURY RATES* (RPK) AMONG NEW JERSEY TOWNS WITH HIGHER SOCIOECONOMIC DEPRIVATION (SED) FOR MALES AND FEMALES AT VARYING LEVELS OF POPULATION SIZE*						
	FEMALES			MALES		
	SIZE OF RESIDENTIAL POPULATION AMONG NJ TOWNS (N=562)					
	LOWER QUARTILE	MEDIAN	HIGHER QUARTILE	LOWER QUARTILE	MEDIAN	HIGHER QUARTILE
RPK 0-14 Years	**1.45**	**1.47**	**1.52**	**2.54**	**2.69**	**3.21**
RPK 15-24 Years	**1.46**	**1.48**	**1.55**	**1.38**	**1.39**	**1.44**
RPK 25-44 Years	**2.50**	**2.62**	**2.98**	**2.82**	**2.96**	**3.41**
RPK 45-64 Years	**1.78**	**1.82**	**1.93**	**2.29**	**2.38**	**2.63**
RPK 65-84 Years	**1.48**	**1.51**	**1.57**	**1.49**	**1.52**	**1.58**
RPK ≥85 Years	**1.38**	**1.39**	**1.44**	**1.44**	**1.46**	**1.52**

* Rates reflect the number of fall-related acute hospitalizations, from 2009 through 2013, per thousand NJ residents per age/sex cohort after adjustment for population density, population size, and level of socioeconomic deprivation as measured by the Townsend Index, as predicted by multivariable regression analysis with robust standard errors.

The rate ratios for males to females among higher and lower SED towns at varying levels of population size appear in Table 20. Results suggest evidence of effect modification in that males had marginally higher rates than females for ages below 65 years, among higher SED towns, with this effect stable across different population sizes.

Table 20: Combined Net Effects of Population Size and Socioeconomic Deprivation on Acute Fall-Related Injury Rates Among Gender and Age Cohorts; Rate Ratios of Males to Females

RATIO OF ACUTE FALL-RELATED INJURY RATES (RPK)* FOR MALES TO FEMALES AMONG AGE COHORTS AT DIFFERENT LEVELS OF RESIDENTIAL POPULATION SIZE IN TOWNS WITH HIGHER AND LOWER SOCIOECONOMIC DEPRIVATION (SED)*			
LOWER & UPPER QUARTILES OF TSI	RESIDENTIAL POPULATION SIZE		
LOW SED	LOWER QUARTILE	MEDIAN	HIGHER QUARTILE
RPK 0-14 Years	**1.2**	**1.1**	**0.9**
RPK 15-24 Years	**2.5**	**2.6**	**2.6**
RPK 25-44 Years	**1.4**	**1.4**	**1.4**
RPK 45-64 Years	**0.8**	**0.8**	**0.7**
RPK 65-84 Years	**0.6**	**0.6**	**0.6**
RPK ≥85 Years	**0.7**	**0.6**	**0.6**
HIGH SED			
RPK 0-14 Years	***2.0***	***2.0***	***2.0***
RPK 15-24 Years	***2.4***	***2.4***	***2.4***
RPK 25-44 Years	***1.6***	***1.6***	***1.6***
RPK 45-64 Years	**1.0**	**1.0**	**1.0**
RPK 65-84 Years	**0.6**	**0.6**	**0.6**
RPK ≥85 Years	**0.7**	**0.7**	**0.7**
*Rates reflect the number of fall-related acute hospitalizations, from 2009 through 2013, per thousand NJ residents per age/sex cohort after adjustment for population density, population size, and level of socioeconomic deprivation as measured by the Townsend Index, as predicted by multivariable regression analysis with robust standard errors.			

4.6 Sensitivity Analysis: Categorical Subsets of Population Size and Density

In the sensitivity analysis, categorical independent variables were used to capture potential non-linear relationships among fall-related injury outcomes. Regression models used quintiles measures of residential population size and residential population density to evaluate; (1) the direction of correlation, (2) the size of the effect, and (3) the distribution shape of effect (see Appendices J through M for complete result tables associated with subacute categorical regression models, and Appendices N through Q for complete result tables associated with acute categorical regression models).

Subacute fall-related injury; impact of population size.

Results associated with categorical models differed from linear regression models in that the relationship of population size to subacute fall-related injury in males varied depending on the residential population count. The impact of population size on subacute fall-related injury rates relative to gender and age group using categorical independent variables is demonstrated in the tables below; Table 21 represents findings associated with the regression analysis which used NCD as the measure for SED, and Table 22 depicts regression results associated with TSI.

Subacute fall-related injury; impact of population size in male cohorts.

Residential population size coefficients associated with the first population quintile measure, those percentiles in the $\leq 20^{th}$ percentile, had a positive correlation to fall injury across all male age cohorts. Irrespective of SED model, population size coefficients were statistically significant in the majority of male age groups. Regression coefficients associated with the 65-84 and ≥ 85 age cohorts did not meet the critical test of statistical significance. Coefficients with the most pronounced, or largest size of the effect, were noted in the youngest and oldest male age groups of 0-14, 65-84, and ≥ 85.

Irrespective of SED measure, population size coefficients associated with the second quintile measure, those falling between 21^{st}-40^{th} percentiles, maintained a positive correlation to subacute fall-related injury across all male age groupings. Associated coefficients were statistically significant in all male age cohorts except the ≥ 85 age cohort. Also, the size of the effect was smaller than results observed in the first quintile measure.

Coefficients related to population size at the third quintile measure, those percentiles falling between the 61^{st}-80^{th} percentiles, showed a negative direction of correlation to subacute fall-related injury in all male age cohorts. Coefficients were not statistically significant regardless of SED measure or age grouping. Moreover, the size of the effect was marginal.

Subacute fall-related injury; impact of population size in female cohorts.

Categorical models used to assess the relationship between residential population size and subacute fall-related injury rates in females produced like results to those observed in males. Regardless of SED measure, population size coefficients associated with the first quintile measure, those percentiles $\leq 20^{th}$ percentile, showed a positive direction of correlation across all female age groups. Population size coefficients were statistically significant in all age cohorts except the 65-84 age group. Coefficients were observed to have the largest size effect in the $\geq$ 85 age group, followed by a fairly sizeable effect in the 0-14 and 15-24 age cohorts.

Population size coefficients related to the second quintile measure, those falling between the 21^{st} - 40^{th} percentiles, continued to demonstrate a positive correlation to subacute fall injury in female age cohorts. Coefficients were statistically significant in all age groups except the $\geq$ 85 age cohort when TSI was used to measure SED. Furthermore, the size of effect in both SED models was smaller than results observed with the $\leq 20^{th}$ quintile measure.

Coefficients associated with the third population size quintile measure, those between the 61^{st} - 80^{th} percentiles, showed an overall negative relationship with subacute fall-related injury for female age groups. Associated coefficients were not statistically significant, regardless of applied SED measure. The size of the effect was marginal and appreciably smaller than the ≤ 20th and 21st - 40th percentiles.

Population size coefficients associated with the fourth quintile, those equal to or above the 81st percentile, were observed to have a negation direction of correlation to subacute fall-related injury in female age cohorts. Coefficients associated with the TSI model were statistically significant in the 0-14, 15-24, and the 45-64 age groups. Coefficients were noted to be statistically significant in 25-44 and 45-64 age groupings with NCD as the SED measure. Regardless of SED measure, the size of the effect was larger than observations associated with the 61st - 80th percentile, similar to the 21st - 40th percentile, and much smaller than the ≤ 20th percentile.

Table 21: Effect of Population Size on Subacute, Emergency Department Visit Fall-Related Injury Rates Among Female and Male Age Cohorts Using County Civil Division Population Quintiles when Neighborhood Concentrated Disadvantage was used to Measure Socioeconomic Deprivation

Effect of Population Size on Subacute Fall-Related Injury Rates (RPK) Using County Civil Division (CCD) Population Quintiles when Neighborhood Concentrated Disadvantage Index (NCD) was used to Measure Socioeconomic Deprivation (SED)												
	0-14 Years		**15-24 Years**		**25-44 Years**		**45-64 Years**		**65-84 Years**		**≥ 85 Years**	
	Female	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**
Intercept; Mid-Quintile Measure for Population Size (41^{st} – 60^{th} Percentile)	133.70	149.90	68.67	88.06	60.58	53.93	88.50	58.13	158.00	99.68	360.70	307.80
CCD Population Size First Quintile Measure (≤ 20^{th} Percentile) *** p<0.01 ** 0<0.05	308.50**	422.00***	205.77***	212.96***	154.78**	122.21***	176.44**	110.83**	349.30**	223.58	921.10**	743.00
CCD Population Size Fourth Quintile Measure (≥81^{st} Percentile) *** p<0.01 ** 0<0.05	104.97	116.81	50.36	64.66**	36.70**	39.08**	65.27**	42.70**	118.79	68.27	280.28	230.27

Table 22: Effect of Population Size on Subacute, Emergency Department Visit Fall-Related Injury Rates Among Female and Male Age Cohorts Using County Civil Division Population Quintiles when Townsend Index was used to Measure Socioeconomic Deprivation

Effect of Population Size on Subacute Fall-Related Injury Rates (RPK) Using County Civil Division (CCD) Population Quintiles when Townsend Index (TSI) was used to Measure Socioeconomic Deprivation (SED)												
	0-14 Years		15-24 Years		25-44 Years		45-64 Years		65-84 Years		≥ 85 Years	
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
Intercept; Mid-Quintile Measure for Population Size (41st – 60th Percentile)	141.20	167.70	74.80	91.80	61.23	53.19	86.36	55.94	159.60	99.84	380.90	312.80
CCD Population Size First Quintile Measure (≤ 20th Percentile) *** p<0.01 ** 0<0.05	306.30**	420.50***	204.10***	211.70***	150.16**	119.18***	171.58**	107.56**	348.40	222.64	921.00	745.50
CCD Population Size Fourth Quintile Measure (≥81st Percentile) *** p<0.01 ** 0<0.05	101.68**	110.74**	47.68**	68.92***	34.25	37.83**	63.55**	41.77	117.82	67.73	274.10	229.80

Subacute fall-related injury; impact of population density.

Findings related to categorical models differed from linear regression models as the relationship of population density to subacute fall-related injury in males varied depending on the residential population count per square mile. Shown in the following tables is the effect of population density on subacute fall-related injury rates on gender and age groupings using categorical variables; Table 23 shows findings associated with the regression analysis which used NCD as the measure for SED, and Table 24 depicts results linked to TSI.

Subacute fall-related injury; impact of population density in male cohorts.

Regardless of the SED measure, residential population density regression coefficients associated with the first quintile measure, those percentiles ≤ 20th percentile, demonstrated a negative direction of correlation to subacute fall-related injury across all male age cohorts. When NCD was used to measure SED, population density coefficients were statistically significant in all male age groups except the 0-14 age cohort. Whereas population density coefficients were only statistically significant in the two oldest male age groups, 65-84 and ≥ 85 years with TSI as the measure for SED. In both SED models, the size of the effect was the largest in the ≥ 85 male age group. However, the overall effect across all age cohorts was substantially smaller than observations associated with population size.

Regardless of SED regression model, population density coefficients associated with the second, third and fourth quintile measures demonstrated an overall positive correlation with subacute fall injury in male age groupings. Coefficients were not statistically significant across all age cohorts. The size of effect differed among the various quintiles and age groups, although the overall effect remained relatively small.

Subacute fall-related injury; impact of population density in female cohorts.

The analysis of residential population density using categorical variables in females revealed similar findings to those observed in males. Regardless of SED measure, population density coefficients associated with the first quintile measure, those percentiles ≤ 20th percentile, showed a negative correlation with subacute fall injury. Coefficients statistical significance varied between SED model and female age groups although the overall size of the effect was small in comparison to the effect noted with population size.

The direction of correlation of population density coefficients associated with the second, third, and fourth quintile measures to subacute fall-related injury varied among female age groups. However, the majority of coefficients demonstrated a positive correlation. Associated population density coefficients were not statistically significant across all age cohorts. The size of effect also varied among the various quintiles and age groups; however, the overall effect was moderately small.

Table 23: Effect of Population Density on Subacute, Emergency Department Visit Fall-Related Injury Rates Among Female and Male Age Cohorts Using County Civil Division Population Quintiles when Neighborhood Concentrated Disadvantage was used to Measure Socioeconomic Deprivation

Effect of Population Density on Subacute Fall-Related Injury Rates (RPK) Using County Civil Division (CCD) Population Quintiles when Neighborhood Concentrated Disadvantage Index (NCD) was used to Measure Socioeconomic Deprivation (SED)												
	0-14 Years		15-24 Years		25-44 Years		45-64 Years		65-84 Years		≥ 85 Years	
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
Intercept; Mid-Quintile Measure for Population Density (41st – 60th Percentile)	133.70	149.90	68.67	88.06	60.58	53.93	88.50	58.13	158.00	99.68	360.70	307.80
CCD Population Density First Quintile Measure (≤ 20th Percentile) *** p<0.01 ** 0<0.05	56.34	52.59	15.54**	34.31**	32.12	28.13**	39.20**	26.67**	61.93**	39.25***	342.42	117.90**
CCD Population Density Fourth Quintile Measure (≥81st Percentile) *** p<0.01 ** 0<0.05	162.83	222.02	78.59	92.25	67.52	55.33	100.96	65.29	203.13	133.16	471.90	387.98

Table 24: Effect of Population Density on Subacute, Emergency Department Visit Fall-Related Injury Rates Among Female and Male Age Cohorts Using County Civil Division Population Quintiles when Townsend Index was used to Measure Socioeconomic Deprivation

Effect of Population Density on Subacute Fall-Related Injury Rates (RPK) Using County Civil Division (CCD) Population Quintiles when Townsend Index (TSI) was used to Measure Socioeconomic Deprivation (SED)												
	0-14 Years		15-24 Years		25-44 Years		45-64 Years		65-84 Years		≥ 85 Years	
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
Intercept; Mid-Quintile Measure for Population Density (41^{st} – 60^{th} Percentile)	141.20	167.70	74.80	91.80	61.23	53.19	86.36	55.94	159.60	99.84	380.90	312.80
CCD Population Density First Quintile Measure (≤ 20^{th} Percentile) *** p<0.01 ** 0<0.05	76.28	89.17	31.56	44.72	46.94	35.71	49.64	32.37	67.47**	42.41**	379.00	119.90**
CCD Population Density Fourth Quintile Measure (≥81^{st} Percentile) *** p<0.01 ** 0<0.05	146.91	191.08	65.70	83.98	57.76	50.77	95.16	62.57	198.80	131.05	439.70	384.59

Acute fall-related injury; impact of population size.

Results associated with categorical models differed from linear regression models as the effect of residential population size on acute fall-related injury varied based on the number of residents by count. Shown in the following tables is the effect of population size on acute fall-related injury rates with respect to gender and age groupings using categorical measures. Table 25 represents findings related to the categorical model using NCD as the measure for SED, and Table 26 shows results associated with the categorical model in which TSI was used to measure SED .

Acute fall-related injury; impact of population size in male cohorts.

Regardless of the SED measure, residential population size coefficients associated with the first quintile measure, those percentiles ≤ 20th percentile, demonstrated a positive direction of correlation to acute fall injury across all male age cohorts. Population size coefficients were statistically significant in the majority of male age groupings, except the 65-84 and ≥ 85 age cohorts. The largest size of effect was noted in the oldest age cohort of ≥ 85 years, followed by the 65-84 age group. Coefficients associated with the remaining male age groupings were observed to have a relatively small effect.

Population size coefficients associated with the second quintile measure, those falling between the 21-40th percentile, continued to show a positive correlation to acute fall-related injury. Coefficients were statistically significant across all male age cohorts except for the 0-14 and 45-64 male age groups in the model using TSI as the SED measure. While the largest effect was in the ≥ 85 age group, overall the size of the effect was smaller than observations associated with the ≤ 20th percentile.

Regression coefficients associated with the third quintile measure, those falling within the 61st - 80th percentile, were shown to have a negative direction of correlation to acute fall injury. Population size coefficients were not statistically significant regardless of the SED measure or male age grouping. Also, the size of the effect was marginal.

In both SED regression models, population size coefficients related to the fourth quintile measure, those percentiles equal to or about the 81st percentile, were noted to have a negative correlation to acute fall-related injury. Associated coefficients were statistically significant across all male age cohorts except for the ≥ 85 age group, and in the 0-14 age group in the TSI model. The size of the effect was smaller than results associated with the ≤ 20th percentile in both SED models.

Acute fall-related injury; impact of population size in female age cohorts.

Results associated with categorical models used to assess the relationship of residential population size to acute fall-related injury rates in females were similar to those observed in males. Irrespective of SED measure, coefficients associated with the first quintile measure, those percentiles ≤ 20th percentile, were positively correlated to acute fall injury. Coefficients were statistically significant in all age cohorts. The size of the effect was nominal across most age groups except the two oldest age cohorts where the largest effect observed was in the ≥ 85 group.

Population size coefficients associated with the second quintile measure, those falling within the 21st - 40th percentile, continued to show a positive correlation to acute fall injury regardless of the SED measure. Coefficients were statistically significant in all female age groups except for the 25-44 age cohort. Also, the size of the effect was smaller than what was noted with the ≤20th percentile, although there remained a sizeable effect in the two oldest age groups.

In both SED models, regression coefficients associated with the third population size quintile, those percentiles falling within the 61st - 80th percentile, indicated a negative correlation with acute fall injury across all female age groups except for the 15-25 age cohort. Coefficients were not statistically significant across all age groupings.

Additionally, the size of the effect was appreciably smaller than the first and second quintile measures.

Population size coefficients associated with the fourth quintile measure, those percentiles ≥ 81st percentile, showed a negative direction of correlation to acute fall-related injury in both SED models and across all female age groups. Coefficients were statistically significant across most female age cohorts. Moreover, the size of effect in both SED models was marginal in most age cohorts, although there was a moderate effect associated with the 65-84 and ≥ 85 age groupings.

Table 25: Effect of Population Size on Acute, Hospital Stay Fall-Related Injury Rates Among Female and Male Age Cohorts Using County Civil Division Population Quintiles when Neighborhood Concentrated Disadvantage was used to Measure Socioeconomic Deprivation

Effect of Population Size on Acute Fall-Related Injury Rates (RPK) Using County Civil Division (CCD) Population Quintiles when Neighborhood Concentrated Index (NCD) was used to Measure Socioeconomic Deprivation (SED)												
	0-14 Years		15-24 Years		25-44 Years		45-64 Years		65-84 Years		≥ 85 Years	
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
Intercept; Mid-Quintile Measure for Population Size (41st – 60th Percentile)	3.63	3.94	2.79	7.44	4.49	5.50	13.14	13.19	57.43	37.78	216.60	154.60
CCD Population Size First Quintile Measure (≤ 20th Percentile) *** p<0.01 ** 0<0.05	8.33**	14.76**	5.88**	13.56**	7.79**	11.74**	22.29**	22.94***	116.31**	71.38	457.50**	331.30
CCD Population Size Fourth Quintile Measure (≥81st Percentile) *** p<0.01 ** 0<0.05	2.85	2.57	2.36	5.44***	2.76***	3.71***	8.57***	8.76***	38.30**	26.70**	151.09**	117.35

Table 26: Effect of Population Size on Acute, Hospital Stay Fall-Related Injury Rates Among Female and Male Age Cohorts Using County Civil Division Population Quintiles when Townsend Index was used to Measure Socioeconomic Deprivation

Effect of Population Size on Acute Fall-Related Injury Rates (RPK) Using County Civil Division (CCD) Population Quintiles when Townsend Index (TSI) was used to Measure Socioeconomic Deprivation (SED)												
	0-14 Years		15-24 Years		25-44 Years		45-64 Years		65-84 Years		≥ 85 Years	
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
Intercept; Mid-Quintile Measure for Population Size (41st – 60th Percentile)	3.79	5.07	2.81	7.57	4.44	5.64	12.60	12.85	56.95	37.53	222.80	157.80
CCD Population Size First Quintile Measure (≤ 20st Percentile) Percentile) *** p<0.01 ** p<0.05	8.31**	14.66**	5.85**	13.50**	7.50**	11.29**	21.69**	22.20***	115.30**	70.86	456.60**	331.00
CCD Population Size Fourth Quintile Measure (≥81st Percentile) *** p<0.01 ** p<0.05	2.78**	2.19**	2.34	5.36***	2.64***	3.45**	8.44***	8.50***	37.96**	26.52**	148.83**	116.09

Acute fall-related injury; impact of population density.

Outcomes associated with categorical models were disparate from linear models as the effect of population density on acute fall-related injury varied depending on the residential population count per square mile. Also, the direction of correlation to acute fall injury was opposing to observations associated with population size. Shown in the following tables is the effect of population density on acute stay fall-related injury rates relative to gender and age cohort; Table 27 exemplifies findings associated with the categorical model using NCD to measure SED, and Table 28 illustrates findings associated with the categorical model using TSI to measure SED.

Acute fall-related injury; impact of population density in male cohorts.

Regardless of SED measure, residential population density coefficients associated with the first quintile measure, those percentiles ≤ 20th percentile, demonstrated a positive direction of correlation to acute fall injury. Associated coefficients were statistically significant across most male age cohorts, except for the 15-24 and ≥ 85 age groups, in addition to the 45-64 male age cohort in the regression model using TSI as the SED measure. Furthermore, the size of the effect was largest in the two oldest male age cohorts, with the most pronounced effect associated with the ≥ 85 age group.

Regardless of the SED measure and age cohort, population density regression coefficients associated with the remaining population quintiles varied regarding the direction of correlation to acute fall injury. Associated coefficients did not meet the critical test of statistical significance across all age groups. Also, the size of the effect was somewhat smaller when compared to the ≤ 20th percentile, with the largest effect, consistently observed in the oldest male age group, irrespective of population quintile.

Acute fall-related injury; impact of population density in female cohorts.

As observed with males, categorical models demonstrated that the relationship of population density to acute fall-related injury in females varied based on the residential population count per square mile. Population density coefficients associated with the first population density quintile measure, those percentiles ≤20th percentile, indicated a negative correlation with acute fall injury in both SED models. Associated coefficients were statistically significant in the 0-14, 25-44, and 45-64 female age groupings. The size of the effect was relatively small in all age groupings excluding the two oldest age cohorts, with the largest effect observed in the ≥ 85 age cohort.

Among the remaining quintile measures, the direction of correlation between population density and acute fall-related injury varied. In the model using NCD as the SED measure, coefficients had a negative correlation in the; 15-24 and the 45-64 female age groups associated with the second quintile measure, the 15-24 age group in the third quintile measure, and the 15-24, 25-44, and 45-64 age cohorts in the fourth quintile measure. When TSI was the applied measure of SED, coefficients had a negative correlation in the; 15-24 female age group associated with the second quintile measure, the 15-24 age group associated with the third quintile measure, and lastly, the 0-14 and 15-24 age cohorts related to the fourth quintile measure. Population density coefficients were not statistically significant across quintile measures and age groups except for the ≥ 85 age cohort in the third quintile measure. Also, the size of the effect was considerably small when compared with observations associated with the first population density quintile measure.

Table 27: Effect of Population Density on Acute, Hospital Stay Fall-Related Injury Rates Among Female and Male Age Cohorts Using County Civil Division Population Quintiles when Neighborhood Concentrated Disadvantage was used to Measure Socioeconomic Deprivation

Effect of Population Density on Acute Fall-Related Injury Rates (RPK) Using County Civil Division (CCD) Population Quintiles when Neighborhood Concentrated Disadvantage Index (NCD) was used to Measure Socioeconomic Deprivation (SED)												
	0-14 Years		15-24 Years		25-44 Years		45-64 Years		65-84 Years		≥ 85 Years	
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
Intercept; Mid-Quintile for Population Density (41st – 60th Percentile)	3.63	3.94	2.79	7.44	4.49	5.50	13.14	13.19	57.43	37.78	216.60	154.60
CCD Population Density First Quintile Measure (≤ 20th Percentile) *** p<0.01 ** 0<0.05	1.03**	0.08***	1.25	4.05	2.47**	2.95**	6.37***	5.37***	24.91**	10.79***	138.96	62.89
CCD Population Density Fourth Quintile Measure (≥81st Percentile) *** p<0.01 ** 0<0.05	4.08	7.42	2.54	6.86	3.61	5.14	12.32	11.49	70.49	43.70	283.69	187.24

Table 28: Effect of Population Density on Acute, Hospital Stay Fall-Related Injury Rates Among Female and Male Age Cohorts Using County Civil Division Population Quintiles when Townsend Index was used to Measure Socioeconomic Deprivation

Effect of Population Density on Acute Fall-Related Injury Rates (RPK) Using County Civil Division (CCD) Population Quintiles when Townsend Index (TSI) was used to Measure Socioeconomic Deprivation (SED)												
	0-14 Years		15-24 Years		25-44 Years		45-64 Years		65-84 Years		≥ 85 Years	
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
Intercept; Mid-Quintile for Population Density Measure (41st – 60th Percentile)	3.79	5.07	2.81	7.57	4.44	5.64	12.60	12.85	56.95	37.53	222.80	157.80
CCD Population Density First Quintile Measure (≤ 20th Percentile) *** p<0.01 ** p<0.05	1.39**	2.40**	1.39	4.47	3.22	4.53	7.16**	6.93**	27.02***	11.87***	152.92	69.90
CCD Population Density Fourth Quintile Measure (≥81st Percentile) *** p<0.01 ** p<0.05	3.78	5.46	2.44	6.53	3.21	4.06	12.04	10.63	69.34	43.11	272.22	181.30

4.7 Summary

The descriptive statistical analysis identified a very large range in fall-related subacute ED visits and acute hospitalization rates among New Jersey's 566 towns. The incidence of fall-related injury was found to be higher among the youngest and the oldest age groups. Also, there was a disproportionately higher incidence of fall-related injury for males in the lower age cohorts and for females in the higher age groupings.

Findings related to the bivariate analysis of the socioenvironmental predictors of fall-related injury demonstrated strong positive associations among population size and density as well as both measures of SED. Linear regression models which regressed socioenvironmental factors onto subacute and acute fall injury rates revealed that TSI was found to be a more robust measure of SED than NCD. Also, TSI had a positive, statistically significant association with both subacute and acute fall injury rates in most age groupings irrespective of gender.

In the regression models that treated population size and density as having linear effects on fall-related injury rates, coefficients associated with these ecologic variables were found to be statistically insignificant or weak. Also, when these coefficients were statistically significant, the direction of correlation was negative and the size of effect was small.

Regression models testing for the independent effects of population size and density revealed a curvilinear relationship with subacute and acute fall injury. Irrespective of gender, population size coefficients associated with the lower quintiles demonstrated a positive correlation, one that was statistically significant across most age cohorts, in addition to a substantial size of effect. Conversely, population size coefficients linked with the higher quintiles showed a negative correlation to fall-related injury, and while statistically significant in most age groupings, the size of the effect was small.

Population density coefficients associated with the lowest quintile were negatively correlated to subacute and acute fall injury, regardless of gender. Unlike population size, statistical significance was observed to be more varied between genders and age groupings. Also, the size of effect when compared to population size was relatively small. Furthermore, while population density coefficients connected with higher quintiles were not statistically significant, they demonstrated a positive correlation to fall injury in the majority of age cohorts for both genders. Overall, the size of the effect was negligible.

In models testing for non-linear relationships among fall-related injury outcomes, TSI had a positive association with both subacute and acute fall-related injury rates irrespective of gender. However, TSI coefficients were only statistically significant in the young and middle adult age cohorts, with one exception in which subacute injury coefficients were also statistically significant in the youngest male cohort, 0-14 years. Similarly, the NCD measure of SED had a positive association with both subacute and acute fall-related injury rates, with coefficients only statistically significant in the young and middle-aged groups for both genders.

CHAPTER 5: SUMMARY OF FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

5.1 Summary of Findings

Fall-related injury continues to rank among the leading causes of ED visits and hospitalizations in persons of all ages (Bergen et al., 2007; Borse et al., 2008; Centers for Disease Control and Injury Prevention, 2013, Murphy et al., 2014). Current prevention efforts may be unsuccessful due to a persistent focus on the elderly as well as a generic approach to place-based effects. Therefore, the central hypothesis of this study was that fall-related injury among defined age and gender cohorts would differ based on the level of residential population size, density, and SED.

To test the stated hypothesis, a retrospective, ecologic population-based cohort methodology was used in the evaluation of fall-related injury for New Jersey over a five-year period. A state-wide hospital registry data link to census data revealed a large range in both subacute and acute injury rates with the highest rates among the youngest and oldest populations. Of note, both variables of age and gender significantly modified the observed effect of subacute as well as acute fall-related injury. Younger males (0-14 years) and older females (≥ 85 years) had a disproportionally higher incidence of subacute fall-related injury. Also, there was a higher incidence of acute fall-related injury in women over 65 years of age.

This study also examined the age and gender-specific incidence of fall-related injury by state county civil divisions (CCDs) using decennial census data. Analysis of the data demonstrated a wide range in both subacute and acute fall injury rates among the

566 CCDs across genders and age groups. Also, subacute and acute fall-related injury rates had a similar geographic distribution within the state. Both were observed to be diffuse, although higher fall-related injury rates were noted among the coastal and metropolitan areas of the state, as well as certain northern and southern rural counties.

Further testing as to whether ecologic factors hypothesized to predict the incidence of fall-related injury were confounded with each other, revealed significant associations among the variables of population size, density, and SED. Also, a correlation analysis showed that both TSI and NCD were significantly inter-related, as were their respective composite variables. Moreover, linear regression models that regressed socioeconomic variables onto fall-related injury had shown TSI to be a more robust measure of SED than NCD given its statistically positive association with subacute and acute fall-related injury in both genders and most age cohorts.

Multivariate regression analysis was used to assess effect modification of residential population size, density, and SED on fall-related injury alternatively for specific gender and age cohorts. Regression models that treated population size and density as a linear relationship with fall-related injury resulted in the absence of well-defined relationships. More affirmatively, there was a weak or insignificant linear effect for population size and density. When these ecologic variables were placed into discrete categorical groups of towns with lower or higher population and population density, a curvilinear effect was revealed. While controlling for age and gender, population size appeared to modify the observed effect of fall-related injury, as rates were noted to be significantly higher among towns with a lower population size. Conversely, population density did not have as clearly a defined relationship with fall-related injury as coefficients varied regarding statistical significance and the size of the effect was minimal.

Multivariate regression analysis demonstrated that SED remained positively associated with both subacute and acute injury outcomes. To exemplify the size of the effect, a change of two standard deviations in the TSI mean resulted in a 53% percent increase (associated with high SED) or a 28% percent decrease (associated with low SED) in the average acute fall injury rate across all male and female age groupings. Socioeconomic deprivation was further observed to interact with age and gender as coefficients with the strongest statistical significance were linked with younger and middle-aged adult groups for both genders, with one exception in which subacute injury coefficients were statistically significant in the youngest male age cohort.

Methods used to profile the size of the joint effect of residential population size and SED on acute fall-related injury rates showed that injury rates were highest among towns falling within the lower population quartile and higher SED quartile across all age groups for both genders. Lastly, it was shown that the largest percent increase in acute injury rates was in the higher population and SED quartiles for younger males (0-14 years) and young as well as middle-aged adults for both gender cohorts (25-44 and 45-64 years).

5.2 Conclusions

The following conclusions were reached related to outcomes of differential vulnerability to fall injury with respect to age, gender, and ecologic covariates of population size, density, and SED:

1. The observed incidence rate of subacute and acute fall-related injury among New Jersey residents was similar to nationally reported data in which the very young and old appear to be highly vulnerable to incurring serious fall-related injuries (Centers for Disease Control and Injury Prevention, 2013; Injury Surveillance Workgroup on Falls, 2006). In addition, state-specific population and hospital-level data confirmed prior findings of effect modification associated with age and gender on fall-related injury rates (Bergen et al., 2007; Borse et al., 2008; Centers for Disease Control and Injury Prevention, 2013; Hartholt et al., 2011; Injury Surveillance Workgroup on Falls, 2006).
2. The overall incidence and distribution pattern of both subacute and acute fall-related injury rates among New Jerseys CCDs widely differed. As New Jersey is noted for its diverse demography, this finding was not unexpected. In fact, this attribute positioned New Jersey as a good fit for the study of variation among people, place, and place-based effects.
3. Consistent with the literature, both TSI and NCD were strongly correlated, as were their composite variables (Kroeger et al., 1997; Messer et al., 2006; Sampson et al., 2002; Schuurman et al., 2007, Wang & Arnold, 2008; Wight et al., 2008). This finding further substantiated their application as study SED

measures. Also, TSI was shown to be a more robust measure of SED than NCD in subacute and acute fall-related injury models for both genders and most age cohorts. Given its sensitivity to detecting material disparities among towns, TSI was more discriminating in predicting fall-related injury.

4. While regression models that treated population size and density as a linear relationship with fall-related injury resulted in the absence of well-defined relationships, they were demonstrated to have a significant association with fall-related injury in regression models that used categorical subsets of these ecologic variables. It was further shown that relationship was curvilinear. Moreover, the pattern of findings was similar in two tests of outcomes, subacute and acute fall-related injury.
    a. Fall-related injury rates were noted to be higher in towns with low residential population. Conversely, fall-related injury rates were observed to be lower in towns with high residential population size.
    b. Population density lacked a defined relationship with fall injury although there remained evidence of effect modification, as well as a bidirectional relationship to fall-related injury rates. Also, population density was noted to have a dissimilar geographic distribution pattern than population size in that it was less evenly dispersed, almost appearing to have two different distributions between northern and southern counties.
    c. The use of residential population size and density to measure urbanicity or level of urbanization was perhaps inadequate in defining urban versus

rural environments. Other variables that address aspects of the built environment and social systems may be necessary considerations. Availability of resources which promote health and well-being, such as communication and transportation infrastructures, as well as healthcare services, educational facilities, and employment opportunities, may vary along the continuum of rural versus urban geographies, which in turn, could increase or decrease fall-related injury risks.

5. Socioeconomic deprivation was observed to have a considerable positive effect on fall-related injury outcomes. In two tests of outcomes, using two separate measures, SED maintained a strongly positive association with subacute and acute fall-related injury rates. Also, SED interacted with age, gender, and population size increasing fall rates in young males, as well as young and middle-aged adults of both genders, residing in highly populated towns with high levels of SED.

An important outcome of this study was a state-specific, epidemiologic profile of fall-related injury, which further identified specific population cohorts as having an increased risk for serious injury. To summarize, population cohorts recognized as being most at risk for fall-related injury included residents of towns with low population size regardless of age and gender, residents of towns with high SED regardless of age and gender, and lastly, young males as well as young and middle-aged adult residents of towns with high population size and high SED. As theorized, socioeconomic determinates of urbanization and SED were shown to have a considerable positive effect on a community's overall fall-related injury risks.

It is suggested that conventional fall risk factors related to physical development and physiologic aging may be stronger determinates for fall injury in the youngest and oldest populations, whereas SED may increase injury risks in younger and middle-aged adults through different mechanisms. For example, neighborhoods having limited housing, schools, and employment opportunities, potentially increase fall risks as substandard housing conditions can present tripping and falling hazards, and limited employment options may carry increased risks for work-related injury, including falls. Also, access challenges to healthcare resources, a common finding in underserved communities, have been recognized in the literature to increase the prevalence of chronic health conditions. This, in turn, can lead to fall risk factors in younger age groups that are typically associated with the elderly (Galea et al., 2011; Machenbach et al., 2008; Stringhini, et al., 2010; O'Campo et al., 2000; World Health Organization, 2009).

Lastly, neighborhood deprivation can be further defined by measurements of social position, such as family support, community membership, and community empowerment (Carstairs, 1995; Sampson et al., 1997; Schuurman et al., 2007). Substantial compromises in these measures may influence fall-related injury outcomes. For instance, working parents who lack family support or access to childcare may leave their children with inadequate supervision and thus increase their children's risk for injurious falls. Additionally, social isolation, particularly in the elderly, has been linked to untoward health outcomes and has been identified as a significant fall risk (Elliot et al., 2009; Garcia et al., 2012; Roe et al., 2009).

While many of the health and social issues associated with high SED can be present in underserved rural and urban neighborhoods, there are fall-related injury risks that are considered unique for each environment. Such as, it has been reported that residents of rural settings exhibit a higher incidence of risk-taking behaviors such as excessive alcohol consumption and inactivity, which can further increase one’s risk for fall-related injuries (Gamm et al., 2003; Hill et al., 2014; Jones et al., 2009; Meit et al., 2014). Additionally, there are environmental vulnerabilities associated with urban geographies, such as crime, depression, substance abuse and exposure to pollutants as well as communicable diseases, which contribute to poor health and increased fall risks (Beck, 2011; Hartelym 2004; Meit et al., 2014; Williams, 2013; World Health Organization, 2008).

Lastly, numerous studies have established that place-related effects are significant determinates of health disparities, and thus health outcomes, however few studies have looked at the impact on fall-related injury outcomes (Bohannon et al., 1999; Hanlon et al., 2002; Mackenbach et al., 2008; Messer et al., 2006; Morenoff & Gannon-Rowley, 2002; O’Campo et al., 2000; Sampson et al., 2007; Stevens & Sogolow, 2005). Moreover, research initiatives that have investigated the impact of ecologic variables on injury outcomes have done so for specific age or gender cohorts, and for injury mechanisms exclusive of falls (Basta et al., 2007; Birken & MacArthur, 2004; Hong et al., 2010; Kamala et al., 2014; Lyons et al., 2003; Siracuse et al., 2012; World Health Organization, 2009; Williams et al., 1997). Therefore, study conclusions associated with the effects of age and gender on fall injury outcomes validate previously published findings, and conclusions associated with ecologic predictors of fall-related injury outcomes have contributed new findings to the body of falls literature.

5.3 Health Policy Recommendations

The following recommendations are offered for public health policy as it relates to public safety and injury prevention:

1. Allocation of funding to support fall-related injury prevention and research initiatives.
    a. Accidental falls are a significant public health issue as they are the primary source of injury-related ED visits and leading cause of hospital admissions for persons of all ages (Centers for Disease Control and Injury Prevention 2013; Murphy et al., 2014)
    b. The untoward effects of fall-related injury reach beyond the individual to families, communities, and healthcare systems. Improved outcomes associated with effective prevention programs would have considerable public health implications as the annual total lifetime costs associated with adult fall-related injury alone is estimated at 110 billion dollars (Verma et al., 2016). Additionally, premature death and loss of social productivity associated with fall-related morbidity and mortality can be minimized.
    c. The U. S. Department of Health and Human Services has recognized fall prevention as a priority for Healthy People 2020 with the goals of promoting health and well-being, decreasing injury rates, reducing

disparities, as well as improving the quality of life for all persons (U.S. Department of Health and Human Services, 2013). This healthcare priority calls for a national, regional, and state-level approach to fall-related injury to capitalize on a collective wisdom and optimize outcomes.

2. Application of a state-specific, fall-related injury profile to guide efforts related to fall risk assessment and prevention initiatives.
    a. Access to such information provides an opportunity for fall-related risk assessment and prevention initiatives to be uniquely tailored or targeted towards at-risk populations, thus enhancing their effectiveness in reducing falls, and minimizing sequelae associated with fall-related injury. While persons of all ages are at risk for sustaining injurious falls, results of this study demonstrate that certain populations have increased risks associated with socioenvironmental factors.
3. Allocation of funding to support participation in state, regional, and national injury databases, as well for enhancements to data collection, analysis, and research processes.
    a. Variation in applied definitions, reporting procedures, and research methodologies greatly impeded the ability to share data and compare study results, as well as perform a meta-analysis. It also impacts the capacity to define the problem of falls regarding scale, the effectiveness of prevention interventions, and fall-related outcome

measures. Although the CDC guidelines provide recommendations for standardizing falls methodology, there remains opportunity to refine and standardize the application of this approach (Campbell et al., 2007; Centers for Disease Control and Injury Prevention, 2009; Injury Surveillance Workgroup on Falls, 2006; Lamb et al., 2005; Schwenk et al., 2008; Schwenk et al., 2012).

5.4 Public Health Nursing Practice Recommendations

The following recommendations are offered for practitioners in the field of public health nursing:

1. Consideration of population-specific socioenvironmental determinants of fall-related injury risks when designing and implementing fall-related risk assessments, prevention programs, and research initiatives.
    a. Socioeconomic deprivation may increase injury risks in younger and middle-aged adults through different mechanisms than traditional fall risk factors related to physical/social development and physiologic aging. Challenges associated with access to wellness programs, healthcare services, and employment opportunities have been recognized to increase the prevalence of chronic health conditions, which can lead to fall-related risk factors in younger populations that are typically associated with the elderly. Therefore, public health nurses caring for young adults diagnosed with chronic health issues should remain cognizant of their increased risk

for sustaining an injurious fall and assess for a decrease in balance, mobility, and physical endurance.

b. Availability of material resources which promote health and well-being as cited above may vary among rural versus urban geographies, particularly those considered underserved. When caring for residents in such settings, public health nurses need to evaluate a patient's ability to secure healthcare services, medications, and other resources necessary for their welfare and optimal health. For example, inadequate neighborhood infrastructures may present unique challenges associated transportation options or travel distances hindering access to healthcare services. Additionally, public health practitioners should recognize social isolation, particularly in the elderly or those with chronic or disabling health conditions, as this phenomenon has been linked to poor health outcomes in addition to being recognized as a considerable fall risk.

c. Public health nurse should assess for educational deficits in high-risk population cohorts regarding injury awareness and prevention. Young parents living in deprived neighborhoods with minimal formal education may not have an awareness of their children's increased fall risks associated with multi-story dwellings, community playgrounds, or certain recreational activity. Additionally, older adults residing in underserved communities or those in social isolation may be lacking in education related to fall risks associated with specific health conditions or medications.

d. Public health nurses need to utilize data available through pooled sources for the identification of population cohorts most at risk for injurious falls. This approach to injury prevention will direct attention and resources to those at-risk populations, and thereby have the most impact on fall injury outcomes.

5.5 Study Strengths

An overarching strength of this study is that identified gaps in the falls literature associated with population disparities were addressed. More specifically, this study investigated the effect of varying levels of urbanization and socioeconomic deprivation on fall-related injuries relative to age and gender. As current research on the epidemiology of fall-related injury is centered on the elderly and the immediate built environment, such an ecologic approach to fall injury allowed for the establishment of a unique signature, or fall-related injury pattern, for the population of an entire state.

Taking into consideration New Jersey's population demographics are exceptionally diverse, it served as an excellent milieu for this study given its ecologic population-based cohort methodology to fall-related injury. Within the state, there are towns with great wealth as well as significant deprivation. Furthermore, there is a considerable range regarding population size and density with New Jersey's largest cities having a population over 250k, to its smallest boroughs having a population of 200 residents or less.

The use of statewide data over a five-year timeline added significant rigor to the study, as it provided the statistical power for strong empirical testing of the hypotheses. Noted earlier, access to the state-wide hospital registry afforded inclusion of over 12.3 million hospitalization records; 2.48 million emergency department visits per year and 1.4 million hospital admissions per year. Additionally, the application of multiple measures of SED strengthened the testing of SED as a risk factor for fall-related injury. Furthermore, convergent validity was demonstrated between NCD and TSI scores or coefficients, as both measures exhibited similar direction and size of SED effect on fall-injury outcomes. Such convergence is a desired characteristic of a multivariate research design.

Lastly, the application of categorical models using discrete measures of population size and density supported a sensitivity analysis of the impact these variables have on subacute and acute fall-related injury rates. Moreover, quintile measures of these ecologic variables were used to further evaluate the direction of correlation, the size of the effect, as well as the distribution shape of effect.

5.6 Study Limitations

The potential for classification bias is present in several areas of the data. Because of the ecologic study design, individual case characteristics were aggregated into counts of emergency department visits and hospitalizations, by gender and age cohorts, to calculate incidence rate ratios of fall-related injury per 1000 residents among New Jersey’s 566 county civil divisions. Census data at the CCD level was then applied to estimate population size, population density, and SED. Therefore, results are based on aggregate group data rather than individual-level data. This methodology potentially introduces aggregation bias in that; confounding is potentially introduced by the grouping process, and census data may not correctly reflect the demographic context of the study population based on its decennial approach.

There is also a concern regarding census data undercounting, which particularly affects socioeconomically deprived populations as well as social minorities. More specifically, estimation of SED at the CCD level is based on variables captured from census or survey data, which may be unreliable for areas with considerably small populations.

Finally, given that the measurement of subacute and acute fall-related injury depends on capture and classification of ED and hospital cases in the hospital uniform billing database, there is the potential for classification bias in that data (Wadman, Muelleman, Coto, & Kellermann, 2003). Measurement error could be associated with variability in case definition and capture related to; emergency department visit or hospital admission, principal diagnosis code and injury code for a fall mechanism (Wadman et al., 2003). To adjust for, or improve reliability and validity of empirical measurement, the timeline for data extrapolation was extended over a five-year period.

5.7 Future Research Recommendations

The following recommendations are offered for future research endeavors associated with fall-related injury:

1. Expanded inquiry into the impact of socioenvironmental factors on fall-related injury across all age and gender cohorts. While several studies have recognized

that place-related effects on health are significant determinates of health disparities, limited studies have considered the impact on fall-related injury outcomes (Bohannon et al., 1999; Hanlon et al., 2002; Mackenbach et al., 2008; Messer et al., 2006; Morenoff & Gannon-Rowley, 2002; O'Campo et al., 2000; Sampson et al., 2007; Stevens & Sogolow, 2005) . Additionally, studies that have investigated the impact of social and ecologic variables on injury outcomes have done so for certain age or gender cohorts, and for injury mechanisms exclusive of falls (Basta et al., 2007; Birken & MacArthur, 2004; Hong et al., 2010; Kamala et al., 2014; Lyons et al., 2003; Siracuse et al., 2012; World Health Organization, 2009; Williams et al., 1997).

2. Inclusion of additional measures of urbanicity other than population size and density to further assess the association to fall-related injury outcomes. While study results established a statistically significant curvilinear relationship of residential population size with fall-related injury rates, there was not a well-defined relationship with population density. Current research focused on the relationship between urbanicity and health outcomes have recognized the limitations of conventional measures of urbanization that center on the proportion of a specific population residing in an area. Therefore it is recommended that additional components of urbanization measures be considered, such as housing, transportation, healthcare, and educational infrastructures (Dahly & Adair, 2007; Gibbs, 1966; Williams, 1985).

3. Further analysis of fall-related injury using injury mechanism codes to expand the overall fall-related risk profile for defined populations and geographies. Additional detail regarding the nature or mechanism of falls can further the identification of specific fall risk factors for discrete populations and assist in the development and implementation of targeted prevention initiatives.
4. Expanded consideration of medical diagnosis codes in the evaluation of fall-related injury across all ages to assist in the identification of high-risk populations. As results of this study suggest, socioenvironmental factors may increase fall-related injury risks in young and middle-aged adults through different mechanisms that influence overall health and susceptibility to chronic illness.

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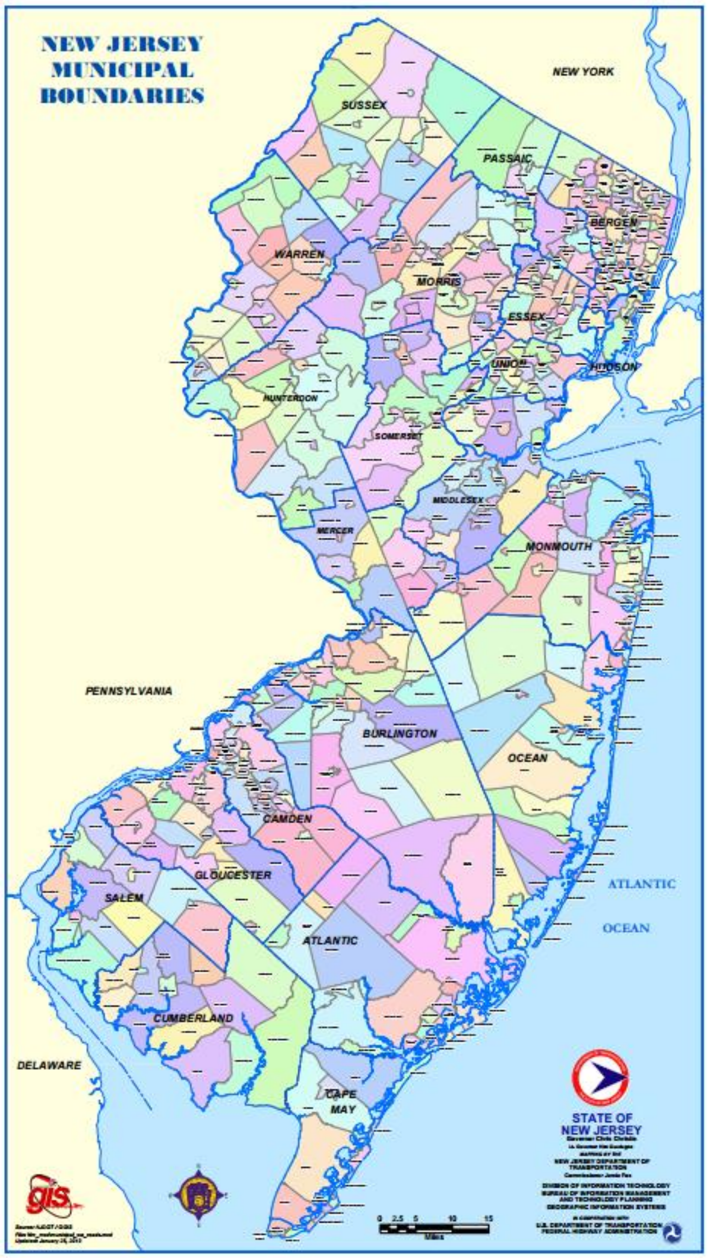
Appendix A Map of New Jersey County Civil Divisions



Appendix B Linear Regression Results Table: Subacute Fall-Related Injury in Male Age Cohorts Using the Neighborhood Concentrated Disadvantage Index to Measure Socioeconomic Deprivation

PREDICTORS OF FALL-RELATED EMERGENCY DEPARTMENT VISITS AMONG MALE AGE COHORTS MEASURING SED WITH NEIGHBORHOOD CONCENTRATED DISADVANTAGE (NCD)						
VARIABLES	RPK MALES 0-14	RPK MALES 15-24	RPK MALES 25-44	RPK MALES 45-64	RPK MALES 65-84	RPK MALES ≥85
POPULATION SIZE 2010	-1.722	-0.988	-0.559	-0.47	-1.136	-3.738
	(0.810)	(0.396)	(0.195)	(0.204)	(0.457)	(1.636)
POPULATION DENSITY 2010	1.472	-0.918	-0.870	-0.267	0.409	-0.398
	(2.219)	(1.012)	(0.724)	(0.762)	(1.621)	(5.433)
COUNTY CIVIL DIVISION NCD 201(	1.557	2.243	3.865	4.579	3.912	7.408
	(3.781)	(1.913)	(1.429)	(1.368)	(2.421)	(8.569)
Constant	251.5	132.7	82.3	77.42	151.9	486.7
	(42.09)	(20.62)	(12.71)	(10.69)	(21.41)	(82.58)
Observations	562	562	562	562	562	560
R-squared	0.010	0.020	0.029	0.043	0.011	0.009
rank	4	4	4	4	4	4
ll_0	-4138	-3672	-3388	-3318	-3913	-4601
ll	-4135	-3666	-3380	-3306	-3910	-4599
r2_a	0.00450	0.0145	0.0237	0.0374	0.00533	0.00342
rss	8.100e+07	1.530e+07	5.503e+06	4.235e+06	3.630e+07	4.450e+08
mss	803076	307910	163909	188121	391074	3.940e+06
rmse	380.9	165.3	99.31	87.11	255.1	894.9
r2	0.00982	0.0198	0.0289	0.0425	0.0107	0.00877
F	1.538	2.414	3.899	5.197	2.461	2.118
df_r	20	20	20	20	20	20
df_m	3	3	3	3	3	3
N_clust	21	21	21	21	21	21
Robust standard errors in parentheses						
*** p<0.01, ** p<0.05, * p<0.1						
Rates reflect the number of emergency department visits from 2009-2013 per thousand New Jersey residents (RPK) per age cohort						

Appendix C Linear Regression Results Table: Subacute Fall-Related Injury in Male Age Cohorts Using the Townsend Index to Measure Socioeconomic Deprivation

PREDICTORS OF FALL-RELATED EMERGENCY DEPARTMENT VISITS AMONG MALE AGE COHORTS MEASURING SED WITH THE TOWNSEND INDEX (TSI)						
VARIABLES	RPK MALES 0-14	RPK MALES 15-24	RPK MALES 25-44	RPK MALES 45-64	RPK MALES 65-84	RPK MALES ≥85
POPULATION SIZE 2010	-2.175**	-1.120***	-0.594***	-0.485**	-1.186**	-3.961**
	(0.773)	(0.383)	(0.188)	(0.194)	(0.445)	(1.656)
POPULATION DENSITY 2010	-5.619	-3.518**	-2.543*	-1.744*	-1.501	-5.891
	(3.638)	(1.606)	(1.283)	(0.878)	(1.729)	(5.634)
COUNTY CIVIL DIVISION TSI 201(	31.81**	13.47**	11.29***	11.23***	12.35**	31.23*
	(11.74)	(5.475)	(3.777)	(3.013)	(5.003)	(17.65)
Constant	282.7	143.6***	88.58***	82.60***	159.2***	509.1***
	(48.71)	(22.93)	(14.84)	(11.28)	(22.74)	(88.13)
Observations	562	562	562	562	562	560
R-squared	0.032	0.038	0.049	0.058	0.015	0.012
rank	4	4	4	4	4	4
ll_0	-4138	-3672	-3388	-3318	-3913	-4601
ll	-4129	-3661	-3374	-3301	-3909	-4598
r2_a	0.0266	0.0331	0.0442	0.0527	0.00965	0.00637
rss	7.920e+07	1.500e+07	5.387e+06	4.167e+06	3.620e+07	4.440e+08
mss	2.598e+06	595078	279472	255619	548690	5.255e+06
rmse	376.7	163.8	98.26	86.42	254.6	893.5
r2	0.0318	0.0382	0.0493	0.0578	0.0149	0.0117
F	4.280	3.072	4.906	6.190	2.949	2.326
df_r	20	20	20	20	20	20
df_m	3	3	3	3	3	3
N_clust	21	21	21	21	21	21
Robust standard errors in parentheses						
*** p<0.01, ** p<0.05, * p<0.1						
Rates reflect the number of emergency department visits from 2009-2013 per thousand New Jersey residents (RPK) per age cohort						

Appendix D Linear Regression Results Table: Subacute Injury in Female Age Cohorts Using the Neighborhood Concentrated Disadvantage Index to Measure Socioeconomic Deprivation

PREDICTORS OF FALL-RELATED EMERGENCY DEPARTMENT VISITS AMONG FEMALE AGE COHORTS MEASURING SED WITH NEIGHBORHOOD CONCENTRATED DISADVANTAGE (NCD)

VARIABLES	FEMALES 0-14	FEMALES 15-24	FEMALES 25-44	FEMALES 45-64	FEMALES 65-84	FEMALES ≥85
POPULATION SIZE 2010	-1.315	-0.966	-0.79	-0.825	-1.691	-4.583
	(0.618)	(0.399)	(0.291)	(0.334)	(0.699)	(1.880)
POPULATION DENSITY 2010	0.591	-0.825	-1.547	-0.143	0.632	-3.827
	(1.713)	(0.994)	(0.929)	(1.111)	(2.464)	(6.329)
COUNTY CIVIL DIVISION NCD 201(	3.314	2.201	5.384	6.65	4.945	6.742
	(2.664)	(1.941)	(2.075)	(2.165)	(3.404)	(9.476)
Constant	191.5	119.9	104.8	121	236.6	625.9
	(32.63)	(21.68)	(19.47)	(16.79)	(33.79)	(104.1)
Observations	562	562	562	562	562	562
R-squared	0.014	0.014	0.017	0.040	0.011	0.008
rank	4	4	4	4	4	4
ll_0	-3897	-3759	-3734	-3571	-4103	-4776
ll	-3893	-3755	-3730	-3559	-4100	-4774
r2_a	0.00863	0.00839	0.0117	0.0349	0.00608	0.00306
rss	3.420e+07	2.090e+07	1.910e+07	1.040e+07	7.150e+07	7.860e+08
mss	483341	290616	330583	435241	823457	6.650e+06
rmse	247.6	193.7	185.1	136.7	357.9	1187
r2	0.0139	0.0137	0.0170	0.0401	0.0114	0.00839
F	1.634	2.446	4.005	4.349	2.270	2.304
df_r	20	20	20	20	20	20
df_m	3	3	3	3	3	3
N_clust	21	21	21	21	21	21

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Rates reflect the number of emergency department visits from 2009-2013 per thousand New Jersey residents (RPK) per age cohort

Appendix E Linear Regression Results Table: Subacute Injury in Female Age Cohorts Using the Townsend Index to Measure Socioeconomic Deprivation

PREDICTORS OF FALL-RELATED EMERGENCY DEPARTMENT VISITS AMONG FEMALE AGE COHORTS MEASURING SED WITH THE TOWNSEND INDEX (TSI)						
VARIABLES	FEMALES 0-14	FEMALES 15-24	FEMALES 25-44	FEMALES 45-64	FEMALES 65-84	FEMALES ≥85
POPULATION SIZE 2010	-1.544	-1.152	-0.875	-0.857	-1.796	-5.066
	(0.608)	(0.402)	(0.316)	(0.310)	(0.696)	(1.829)
POPULATION DENSITY 2010	-3.757	-4.216	-4.42	-2.63	-2.407	-12.92
	(2.258)	(2.033)	(2.307)	(1.324)	(2.654)	(9.219)
COUNTY CIVIL DIVISION TSI 2010	22.05	16.79	18.03	17.76	18.26	45.93
	(8.275)	(5.982)	(6.510)	(4.740)	(7.720)	(23.62)
Constant	209.9	134.4	115.9	130.1	248.7	664.5
	(36.30)	(26.45)	(25.27)	(17.65)	(36.87)	(117.1)
Observations	562	562	562	562	562	562
R-squared	0.037	0.036	0.036	0.061	0.017	0.013
rank	4	4	4	4	4	4
ll_0	-3897	-3759	-3734	-3571	-4103	-4776
ll	-3887	-3749	-3724	-3553	-4098	-4773
r2_a	0.0315	0.0306	0.0305	0.0563	0.0118	0.00742
rss	3.340e+07	2.050e+07	1.880e+07	1.020e+07	7.100e+07	7.820e+08
mss	1.272e+06	758988	693961	666532	1.236e+06	1.010e+07
rmse	244.8	191.5	183.3	135.2	356.8	1184
r2	0.0367	0.0358	0.0357	0.0614	0.0171	0.0127
F	2.949	3.484	4.970	6.341	2.595	2.597
df_r	20	20	20	20	20	20
df_m	3	3	3	3	3	3
N_clust	21	21	21	21	21	21
Robust standard errors in parentheses						
*** p<0.01, ** p<0.05, * p<0.1						
Rates reflect the number of emergency department visits from 2009-2013 per thousand New Jersey residents (RPK) per age cohort						

Appendix F Linear Regression Results Table: Acute Injury in Male Age Cohorts Using the Neighborhood Concentrated Disadvantage Index to Measure Socioeconomic Deprivation

PREDICTORS OF FALL-RELATED ACUTE HOSPITAL STAYS AMONG MALE AGE COHORTS MEASURING SED WITH NEIGHBORHOOD CONCENTRATED DISADVANTAGE (NCD)						
VARIABLES	RPK MALES 0-14	RPK MALES 15-24	RPK MALES 25-44	RPK MALES 45-64	RPK MALES 65-84	RPK MALES ≥85
POPULATION SIZE 2010	-0.0639	-0.0606	-0.0525	-0.107	-0.372	-1.751
	(0.0313)	(0.0242)	(0.0188)	(0.0339)	(0.131)	(0.591)
POPULATION DENSITY 2010	0.0887	-0.0198	-0.12	-0.137	0.130	0.0783
	(0.0762)	(0.0588)	(0.0547)	(0.0793)	(0.479)	(2.022)
COUNTY CIVIL DIVISION NCD 201	-0.0239	0.120	0.437	0.914	1.468	4.408
	(0.163)	(0.111)	(0.139)	(0.163)	(0.339)	(2.537)
Constant	7.941	8.65	8.085	14.86	49.44	228
	(1.822)	(1.057)	(1.031)	(1.157)	(5.014)	(25.38)
Observations	562	562	562	562	562	560
R-squared	0.004	0.016	0.014	0.058	0.016	0.011
rank	4	4	4	4	4	4
ll_0	-2553	-2145	-2334	-2336	-3196	-4109
ll	-2552	-2140	-2330	-2319	-3192	-4106
r2_a	-0.00125	0.0104	0.00867	0.0531	0.0102	0.00584
rss	289518	66824	131263	126165	2.822e+06	7.660e+07
mss	1192	1067	1860	7791	44537	865032
rmse	22.78	10.94	15.34	15.04	71.11	371.1
r2	0.00410	0.0157	0.0140	0.0582	0.0155	0.0112
F	1.886	2.112	5.374	10.88	9.040	4.415
df_r	20	20	20	20	20	20
df_m	3	3	3	3	3	3
N_clust	21	21	21	21	21	21
Robust standard errors in parentheses						
*** p<0.01, ** p<0.05, * p<0.1						
Rates reflect the number of acute hospital stays from 2009-2013 per thousand New Jersey residents (RPK) per age cohort						

Appendix G Linear Regression Results Table: Acute Injury in Male Age Cohorts Using the Townsend Index to Measure Socioeconomic Deprivation

PREDICTORS OF FALL-RELATED ACUTE HOSPITAL STAYS AMONG MALE AGE COHORTS MEASURING SED WITH THE TOWNSEND INDEX (TSI)						
VARIABLES	RPK MALES 0-14	RPK MALES 15-24	RPK MALES 25-44	RPK MALES 45-64	RPK MALES 65-84	RPK MALES ≥85
POPULATION SIZE 2010	-0.0908	-0.0662	-0.062	-0.113	-0.388	-1.886
	(0.0355)	(0.0232)	(0.0189)	(0.0278)	(0.120)	(0.578)
POPULATION DENSITY 2010	-0.297	-0.137	-0.391	-0.49	-0.550	-3.219
	(0.230)	(0.0702)	(0.148)	(0.0580)	(0.378)	(1.769)
COUNTY CIVIL DIVISION TSI 2010	1.613	0.628	1.626	2.488	4.475	18.71
	(0.615)	(0.230)	(0.392)	(0.274)	(0.574)	(5.036)
Constant	9.674	9.136	9.162	16.16	52.02	241.5
	(2.527)	(1.117)	(1.411)	(1.162)	(4.770)	(26.60)
Observations	562	562	562	562	562	560
R-squared	0.020	0.025	0.039	0.094	0.022	0.017
rank	4	4	4	4	4	4
ll_0	-2553	-2145	-2334	-2336	-3196	-4109
ll	-2548	-2138	-2323	-2308	-3190	-4104
r2_a	0.0149	0.0193	0.0335	0.0891	0.0171	0.0120
rss	284858	66227	127971	121372	2.802e+06	7.610e+07
mss	5852	1663	5152	12583	64152	1.339e+06
rmse	22.59	10.89	15.14	14.75	70.87	369.9
r2	0.0201	0.0245	0.0387	0.0939	0.0224	0.0173
F	8.498	3.087	10.35	40.50	23.31	5.645
df_r	20	20	20	20	20	20
df_m	3	3	3	3	3	3
N_clust	21	21	21	21	21	21
Robust standard errors in parentheses						
*** p<0.01, ** p<0.05, * p<0.1						
Rates reflect the number of acute hospital stays from 2009-2013 per thousand New Jersey residents (RPK) per age cohort						

Appendix H Linear Regression Results Table: Acute Injury in Female Age Cohorts Using the Neighborhood Concentrated Disadvantage Index to Measure Socioeconomic Deprivation

PREDICTORS OF FALL-RELATED ACUTE HOSPITAL STAYS AMONG FEMALE AGE COHORTS MEASURING SED WITH NEIGHBORHOOD CONCENTRATED DISADVANTAGE (NCD)						
VARIABLES	FEMALES 0-14	FEMALES 15-24	FEMALES 25-44	FEMALES 45-64	FEMALES 65-84	FEMALES ≥85
POPULATION SIZE 2010	-0.031	-0.0267	-0.0399	-0.122	-0.652	-2.449
	(0.0153)	(0.00985)	(0.0122)	(0.0376)	(0.206)	(0.851)
POPULATION DENSITY 2010	0.0253	-0.0139	-0.0634	-0.126	-0.0630	-0.959
	(0.0385)	(0.0222)	(0.0340)	(0.0757)	(0.626)	(2.638)
COUNTY CIVIL DIVISION NCD 201	0.0371	0.0788	0.315	0.853	2.548	5.025
	(0.0727)	(0.0602)	(0.109)	(0.196)	(0.871)	(3.441)
Constant	4.7	3.576	5.176	16.18	84.36	341.5
	(0.742)	(0.425)	(0.483)	(1.243)	(8.129)	(37.61)
Observations	562	562	562	562	562	562
R-squared	0.005	0.012	0.032	0.052	0.020	0.013
rank	4	4	4	4	4	4
ll_0	-2049	-1779	-1922	-2368	-3445	-4269
ll	-2047	-1775	-1913	-2353	-3439	-4265
r2_a	-2.11e-06	0.00646	0.0265	0.0467	0.0144	0.00814
rss	48016	18248	29780	142572	6.804e+06	1.290e+08
mss	258.0	217.3	975.0	7789	136708	1.753e+06
rmse	9.276	5.719	7.305	15.98	110.4	480.1
r2	0.00535	0.0118	0.0317	0.0518	0.0197	0.0134
F	1.597	2.555	4.973	6.870	5.029	3.079
df_r	20	20	20	20	20	20
df_m	3	3	3	3	3	3
N_clust	21	21	21	21	21	21
Robust standard errors in parentheses						
*** p<0.01, ** p<0.05, * p<0.1						
Rates reflect the number of acute hospital stays from 2009-2013 per thousand New Jersey residents (RPK) per age cohort						

Appendix I Linear Regression Results Table: Acute Injury in Female Age Cohorts Using the Townsend Index to Measure Socioeconomic Deprivation

PREDICTORS OF FALL-RELATED ACUTE HOSPITAL STAYS AMONG FEMALE AGE COHORTS MEASURING SED WITH THE TOWNSEND INDEX (TSI)						
VARIABLES	FEMALES 0-14	FEMALES 15-24	FEMALES 25-44	FEMALES 45-64	FEMALES 65-84	FEMALES ≥85
POPULATION SIZE 2010	-0.0361	-0.0287	-0.043	-0.121	-0.675	-2.658
	(0.0149)	(0.00915)	(0.00982)	(0.0327)	(0.192)	(0.793)
POPULATION DENSITY 2010	-0.0605	-0.0655	-0.204	-0.372	-1.168	-5.528
	(0.0555)	(0.0405)	(0.0588)	(0.0647)	(0.539)	(3.189)
COUNTY CIVIL DIVISION TSI 2010	0.404	0.304	0.936	1.967	7.45	24.85
	(0.253)	(0.147)	(0.171)	(0.318)	(1.621)	(8.328)
Constant	5.072	3.783	5.705	17.01	88.51	360.3
	(0.729)	(0.444)	(0.567)	(1.283)	(8.313)	(41.64)
Observations	562	562	562	562	562	562
R-squared	0.011	0.018	0.058	0.061	0.027	0.020
rank	4	4	4	4	4	4
ll_0	-2049	-1779	-1922	-2368	-3445	-4269
ll	-2046	-1774	-1905	-2350	-3437	-4263
r2_a	0.00589	0.0129	0.0534	0.0563	0.0217	0.0152
rss	47733	18129	28958	141138	6.753e+06	1.280e+08
mss	540.7	336.4	1797	9224	187132	2.668e+06
rmse	9.249	5.700	7.204	15.90	110.0	478.4
r2	0.0112	0.0182	0.0584	0.0613	0.0270	0.0205
F	2.411	3.658	11.88	14.55	7.791	4.103
df_r	20	20	20	20	20	20
df_m	3	3	3	3	3	3
N_clust	21	21	21	21	21	21
Robust standard errors in parentheses						
*** p<0.01, ** p<0.05, * p<0.1						
Rates reflect the number of acute hospital stays from 2009-2013 per thousand New Jersey residents (RPK) per age cohort						

Appendix J Quintile Measure Regression Results Table: Subacute Injury in Male Age Cohorts Using the Neighborhood Concentrated Disadvantage Index to Measure Socioeconomic Deprivation

PREDICTORS OF FALL-RELATED ACUTE HOSPITAL STAYS AMONG MALE AGE COHORTS MEASURING SED WITH THE TOWNSEND INDEX (TSI)						
VARIABLES	RPK MALES 0-14	RPK MALES 15-24	RPK MALES 25-44	RPK MALES 45-64	RPK MALES 65-84	RPK MALES ≥85
POPULATION SIZE 2010	-0.0908	-0.0662	-0.062	-0.113	-0.388	-1.886
	(0.0355)	(0.0232)	(0.0189)	(0.0278)	(0.120)	(0.578)
POPULATION DENSITY 2010	-0.297	-0.137	-0.391	-0.49	-0.550	-3.219
	(0.230)	(0.0702)	(0.148)	(0.0580)	(0.378)	(1.769)
COUNTY CIVIL DIVISION TSI 2010	1.613	0.628	1.626	2.488	4.475	18.71
	(0.615)	(0.230)	(0.392)	(0.274)	(0.574)	(5.036)
Constant	9.674	9.136	9.162	16.16	52.02	241.5
	(2.527)	(1.117)	(1.411)	(1.162)	(4.770)	(26.60)
Observations	562	562	562	562	562	560
R-squared	0.020	0.025	0.039	0.094	0.022	0.017
rank	4	4	4	4	4	4
ll_0	-2553	-2145	-2334	-2336	-3196	-4109
ll	-2548	-2138	-2323	-2308	-3190	-4104
r2_a	0.0149	0.0193	0.0335	0.0891	0.0171	0.0120
rss	284858	66227	127971	121372	2.802e+06	7.610e+07
mss	5852	1663	5152	12583	64152	1.339e+06
rmse	22.59	10.89	15.14	14.75	70.87	369.9
r2	0.0201	0.0245	0.0387	0.0939	0.0224	0.0173
F	8.498	3.087	10.35	40.50	23.31	5.645
df_r	20	20	20	20	20	20
df_m	3	3	3	3	3	3
N_clust	21	21	21	21	21	21
Robust standard errors in parentheses						
*** p<0.01, ** p<0.05, * p<0.1						
Rates reflect the number of acute hospital stays from 2009-2013 per thousand New Jersey residents (RPK) per age cohort						

Appendix K Quintile Measure Regression Results Table: Subacute Injury in Male Age Cohorts Using the Townsend Index to Measure Socioeconomic Deprivation

PREDICTORS OF FALL-RELATED ACUTE HOSPITAL STAYS AMONG FEMALE AGE COHORTS MEASURING SED WITH THE TOWNSEND INDEX (TSI)						
VARIABLES	RPK FEMALES 0-14	RPK FEMALES 15-24	RPK FEMALES 25-44	RPK FEMALES 45-64	RPK FEMALES 65-84	RPK FEMALES ≥85
POPULATION SIZE 2010	-0.0361	-0.0287	-0.043	-0.121	-0.675	-2.658
	(0.0149)	(0.00915)	(0.00982)	(0.0327)	(0.192)	(0.793)
POPULATION DENSITY 2010	-0.0605	-0.0655	-0.204	-0.372	-1.168	-5.528
	(0.0555)	(0.0405)	(0.0588)	(0.0647)	(0.539)	(3.189)
COUNTY CIVIL DIVISION TSI 2010	0.404	0.304	0.936	1.967	7.45	24.85
	(0.253)	(0.147)	(0.171)	(0.318)	(1.621)	(8.328)
Constant	5.072	3.783	5.705	17.01	88.51	360.3
	(0.729)	(0.444)	(0.567)	(1.283)	(8.313)	(41.64)
Observations	562	562	562	562	562	562
R-squared	0.011	0.018	0.058	0.061	0.027	0.020
rank	4	4	4	4	4	4
ll_0	-2049	-1779	-1922	-2368	-3445	-4269
ll	-2046	-1774	-1905	-2350	-3437	-4263
r2_a	0.00589	0.0129	0.0534	0.0563	0.0217	0.0152
rss	47733	18129	28958	141138	6.753e+06	1.280e+08
mss	540.7	336.4	1797	9224	187132	2.668e+06
rmse	9.249	5.700	7.204	15.90	110.0	478.4
r2	0.0112	0.0182	0.0584	0.0613	0.0270	0.0205
F	2.411	3.658	11.88	14.55	7.791	4.103
df_r	20	20	20	20	20	20
df_m	3	3	3	3	3	3
N_clust	21	21	21	21	21	21
Robust standard errors in parentheses						
*** p<0.01, ** p<0.05, * p<0.1						
Rates reflect the number of acute hospital stays from 2009-2013 per thousand New Jersey residents (RPK) per age cohort						

Appendix L Quintile Measure Regression Results Table: Subacute Injury in Female Age Cohorts Using the Neighborhood Concentrated Disadvantage Index to Measure Socioeconomic Deprivation

PREDICTORS OF FALL-RELATED EMERGENCY DEPARTMENT VISITS AMONG FEMALE AGE COHORTS
MEASURING SED WITH NEIGHBORHOOD CONCENTRATED DISADVANTAGE (NCD) & QUINTILE MEASURES OF POPULATION

VARIABLES	RPK FEMALES	RPK FEMALES	RPK FEMALES	RPK FEMALES	RPK FEMALES	RPK FEMALES
CCD POPULATION 2010 <20 PERCENTILE	174.8**	137.1***	94.20**	87.94**	191.3*	560.4**
	(65.64)	(42.04)	(38.31)	(32.38)	(92.57)	(249.1)
CCD POPULATION 2010 21-40 PERCENTILE	62.15***	48.92***	35.18***	37.62***	88.89***	202.4**
	(14.45)	(11.89)	(9.135)	(9.215)	(30.82)	(94.85)
CCD POPULATION 2010 61-80 PERCENTILE	-0.0916	-5.711	-8.571	0.665	-2.078	-19.07
	(18.01)	(11.49)	(9.787)	(11.57)	(29.79)	(80.03)
CCD POPULATION 2010 ≥81 PERCENTILE	-28.73*	-18.31*	-23.88**	-23.23**	-39.21	-80.42
	(16.37)	(10.28)	(9.007)	(10.70)	(25.08)	(64.74)
CCD POPULATION DENSITY <20 PERCENTILE	-77.36*	-53.13**	-28.46*	-49.30**	-96.07**	-18.28
	(43.77)	(21.80)	(15.95)	(18.92)	(36.34)	(197.6)
CCD POPULATION DENSITY 21-40 PERCENTILE	1.680	24.62	38.12	0.00350	-1.239	26.59
	(53.99)	(42.95)	(47.74)	(23.29)	(47.90)	(172.3)
CCD POPULATION DENSITY 61-80 PERCENTILE	37.19	25.37	21.17	30.63	87.75	137.0
	(21.61)	(17.97)	(13.79)	(19.98)	(64.23)	(90.67)
CCD POPULATION DENSITY ≥81 PERCENTILE	29.13	9.921	6.943	12.46	45.13	111.2
	(27.75)	(18.43)	(18.45)	(15.49)	(36.85)	(129.9)
CCD NCD 2010	0.240	0.0976	3.874*	4.678**	0.408	-4.466
	(2.379)	(1.957)	(2.015)	(1.881)	(3.418)	(7.506)
Constant	133.7***	68.67***	60.58***	88.50***	158.0***	360.7***
	(26.24)	(14.85)	(14.09)	(14.67)	(31.48)	(81.00)
Observations	562	562	562	562	562	562
R-squared	0.089	0.091	0.061	0.112	0.064	0.036
rank	10	10	10	10	10	10
ll_0	-3897	-3759	-3734	-3571	-4103	-4776
ll	-3871	-3732	-3717	-3538	-4085	-4766
r2_a	0.0742	0.0761	0.0462	0.0971	0.0483	0.0204
rss	3.160e+07	1.930e+07	1.830e+07	9.652e+06	6.770e+07	7.640e+08
mss	3.091e+06	1.931e+06	1.195e+06	1.213e+06	4.598e+06	2.860e+07
rmse	239.3	187.0	181.8	132.2	350.2	1176
r2	0.0891	0.0910	0.0615	0.112	0.0636	0.0361
F	5.752	2.937	3.032	5.100	2.869	4.680
df_r	20	20	20	20	20	20
df_m	9	9	9	9	9	9
N_clust	21	21	21	21	21	21

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Rates reflect the number of emergency department visits from 2009-2013 per thousand New Jersey residents (RPK) per age cohort
CCD - County Civil Division

Appendix M Quintile Measure Regression Results Table: Subacute Injury in Female Age Cohorts Using the Townsend Index to Measure Socioeconomic Deprivation

PREDICTORS OF FALL-RELATED EMERGENCY DEPARTMENT VISITS AMONG FEMALE AGE COHORTS MEASURING SED WITH THE TOWNSEND INDEX (TSI) & QUINTILE MEASURES OF POPULATION SIZE & DENSITY

VARIABLES	RPK FEMALES	RPK FEMALES	RPK FEMALES	RPK FEMALES	RPK FEMALES	RPK FEMALES
CCD POPULATION 2010 <20 PERCENTILE	165.1**	129.3***	88.93**	85.22**	188.8*	540.1**
	(63.45)	(39.10)	(32.17)	(31.57)	(91.71)	(242.5)
CCD POPULATION 2010 21-40 PERCENTILE	56.31***	44.19***	32.08***	36.09***	87.37***	190.0*
	(13.98)	(11.47)	(8.254)	(9.307)	(30.50)	(93.82)
CCD POPULATION 2010 61-80 PERCENTILE	-2.769	-7.835	-11.73	-2.173	-2.937	-22.45
	(17.12)	(11.27)	(10.26)	(12.25)	(30.30)	(76.60)
CCD POPULATION 2010 ≥81 PERCENTILE	-39.52**	-27.12**	-26.98*	-22.81**	-41.78*	-106.8*
	(15.01)	(11.30)	(13.05)	(10.93)	(23.91)	(60.80)
CCD POPULATION DENSITY <20 PERCENTILE	-64.92	-43.24*	-14.29	-36.72*	-92.13**	-1.906
	(41.97)	(21.62)	(15.85)	(18.53)	(38.33)	(207.1)
CCD POPULATION DENSITY 21-40 PERCENTILE	8.892	30.39	44.82	5.431	0.909	38.08
	(52.22)	(44.29)	(50.50)	(23.29)	(48.92)	(172.0)
CCD POPULATION DENSITY 61-80 PERCENTILE	32.39	21.37	22.51	34.17	86.85	121.6
	(20.91)	(16.97)	(13.36)	(20.69)	(62.48)	(89.42)
CCD POPULATION DENSITY ≥81 PERCENTILE	5.718	-9.100	-3.475	8.807	39.20	58.80
	(32.90)	(16.84)	(14.49)	(16.77)	(39.32)	(136.1)
CCD TSI 2010	10.43*	8.303*	11.44**	10.00**	3.268	14.32
	(6.018)	(4.505)	(5.339)	(4.052)	(7.171)	(19.65)
Constant	141.2***	74.80***	61.23***	86.36***	159.6***	380.9***
	(25.40)	(12.97)	(12.31)	(14.86)	(30.71)	(76.87)
Observations	562	562	562	562	562	562
R-squared	0.095	0.097	0.069	0.115	0.064	0.036
rank	10	10	10	10	10	10
ll_0	-3897	-3759	-3734	-3571	-4103	-4776
ll	-3869	-3730	-3714	-3536	-4085	-4766
r2_a	0.0806	0.0827	0.0540	0.101	0.0486	0.0207
rss	3.140e+07	1.920e+07	1.810e+07	9.614e+06	6.770e+07	7.640e+08
mss	3.307e+06	2.068e+06	1.345e+06	1.250e+06	4.618e+06	2.880e+07
rmse	238.5	186.3	181.1	132.0	350.1	1176
r2	0.0953	0.0974	0.0692	0.115	0.0639	0.0364
F	5.502	3.194	2.835	4.701	2.842	3.131
df_r	20	20	20	20	20	20
df_m	9	9	9	9	9	9
N_clust	21	21	21	21	21	21

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Rates reflect the number of emergency department visits from 2009-2013 per thousand New Jersey residents (RPK) per age cohort
CCD - County Civil Division

Appendix N Quintile Measure Regression Results Table: Acute Injury in Male Age Cohorts Using the Neighborhood Concentrated Disadvantage to Measure Socioeconomic Deprivation

PREDICTORS OF FALL-RELATED ACUTE HOSPITAL STAYS AMONG MALE AGE COHORTS MEASURING SED WITH NEIGHBORHOOD CONCENTRATED DISADVANTAGE (NCD) & QUINTILE MEASURES OF						
VARIABLES	RPK MALES	RPK MALES	RPK MALES	RPK MALES	RPK MALES	RPK MALES
CCD POPULATION 2010 <20 PERCENTILE	10.82**	6.125**	6.242**	9.752***	33.60*	176.7*
	(4.654)	(2.655)	(2.479)	(2.900)	(16.26)	(85.40)
CCD POPULATION 2010 21-40 PERCENTILE	2.389**	2.352**	1.811***	2.486**	17.29**	89.73**
	(0.878)	(0.907)	(0.589)	(1.135)	(6.636)	(39.51)
CCD POPULATION 2010 61-80 PERCENTILE	-1.122	-0.838	-0.477	-1.372	-2.537	-11.06
	(1.194)	(0.689)	(0.720)	(1.050)	(5.415)	(20.41)
CCD POPULATION 2010 ≥81 PERCENTILE	-1.373*	-2.007***	-1.791***	-4.438***	-11.08**	-37.25
	(0.778)	(0.682)	(0.486)	(1.139)	(4.973)	(25.19)
CCD POPULATION DENSITY <20 PERCENTILE	-3.863***	-3.391*	-2.552**	-7.820***	-26.99***	-91.73*
	(0.997)	(1.816)	(0.946)	(2.447)	(6.892)	(46.07)
CCD POPULATION DENSITY 21-40 PERCENTILE	3.986	-1.039	2.728	-0.893	-3.550	-19.42
	(5.528)	(1.259)	(3.323)	(2.654)	(7.899)	(35.66)
CCD POPULATION DENSITY 61-80 PERCENTILE	2.417	0.388	1.274	1.644	18.91	95.83
	(1.599)	(1.313)	(1.065)	(1.945)	(14.47)	(64.82)
CCD POPULATION DENSITY ≥81 PERCENTILE	3.488	-0.583	-0.368	-1.705	5.927	32.64
	(2.285)	(1.390)	(1.510)	(1.908)	(8.331)	(45.10)
CCD NCD 2010	-0.166	0.0231	0.357***	0.712***	0.505	-0.360
	(0.179)	(0.0975)	(0.124)	(0.123)	(0.440)	(2.626)
Constant	3.944**	7.444***	5.501***	13.19***	37.78***	154.6***
	(1.439)	(1.033)	(1.054)	(1.684)	(7.110)	(30.75)
Observations	562	562	562	562	562	560
R-squared	0.045	0.071	0.047	0.147	0.074	0.056
rank	10	10	10	10	10	10
ll_0	-2553	-2145	-2334	-2336	-3196	-4109
ll	-2540	-2124	-2320	-2291	-3175	-4093
r2_a	0.0295	0.0555	0.0311	0.133	0.0589	0.0407
rss	277604	63091	126915	114231	2.654e+06	7.310e+07
mss	13105	4799	6208	19725	212005	4.348e+06
rmse	22.43	10.69	15.16	14.39	69.34	364.5
r2	0.0451	0.0707	0.0466	0.147	0.0740	0.0562
F	12.96	4.660	18.54	14.95	5.268	2.884
df_r	20	20	20	20	20	20
df_m	9	9	9	9	9	9
N_clust	21	21	21	21	21	21

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Rates reflect the number of acute hospital stays from 2009-2013 per thousand New Jersey residents (RPK) per age cohort
CCD - County Civil Division

Appendix O Quintile Measure Regression Results Table: Acute Injury in Male Age Cohorts Using the Townsend Index to Measure Socioeconomic Deprivation

PREDICTORS OF FALL-RELATED ACUTE HOSPITAL STAYS AMONG MALE AGE COHORTS MEASURING SED WITH THE TOWNSEND INDEX (TSI) & QUINTILE MEASURES OF POPULATION SIZE & DENSITY						
VARIABLES	RPK MALES 0-14	RPK MALES 15-24	RPK MALES 25-44	RPK MALES 45-64	RPK MALES 65-84	RPK MALES ≥85
CCD POPULATION 2010 <20 PERCENTILE	9.594**	5.931**	5.651**	9.356***	33.33*	173.2*
	(3.967)	(2.644)	(2.032)	(2.837)	(16.38)	(83.38)
CCD POPULATION 2010 21-40 PERCENTILE	1.644*	2.236**	1.461**	2.263*	17.14**	87.51**
	(0.792)	(0.895)	(0.530)	(1.113)	(6.622)	(40.57)
CCD POPULATION 2010 61-80 PERCENTILE	-1.372	-0.900	-0.796	-1.800	-2.838	-11.89
	(1.169)	(0.663)	(0.725)	(1.142)	(5.581)	(19.86)
CCD POPULATION 2010 ≥81 PERCENTILE	-2.888**	-2.210***	-2.196**	-4.356***	-11.01**	-41.71*
	(1.368)	(0.617)	(0.835)	(1.250)	(5.044)	(21.94)
CCD POPULATION DENSITY <20 PERCENTILE	-2.671**	-3.105*	-1.115	-5.926**	-25.66***	-87.90*
	(1.143)	(1.769)	(1.116)	(2.422)	(6.987)	(45.78)
CCD POPULATION DENSITY 21-40 PERCENTILE	4.756	-0.881	3.422	-0.0793	-2.980	-16.86
	(5.823)	(1.216)	(3.507)	(2.558)	(7.961)	(33.79)
CCD POPULATION DENSITY 61-80 PERCENTILE	1.600	0.311	1.343	2.192	19.30	93.54
	(1.420)	(1.275)	(1.073)	(2.027)	(14.34)	(62.82)
CCD POPULATION DENSITY ≥81 PERCENTILE	0.397	-1.042	-1.585	-2.220	5.582	23.50
	(1.142)	(1.324)	(1.030)	(1.921)	(8.496)	(46.30)
CCD TSI 2010	1.022**	0.238	1.165***	1.505***	1.058	3.268
	(0.436)	(0.173)	(0.328)	(0.287)	(0.945)	(4.280)
Constant	5.071***	7.577***	5.644***	12.85***	37.53***	157.8***
	(0.944)	(0.935)	(0.960)	(1.896)	(7.226)	(28.77)
Observations	562	562	562	562	562	560
R-squared	0.052	0.072	0.060	0.153	0.074	0.056
rank	10	10	10	10	10	10
ll_0	-2553	-2145	-2334	-2336	-3196	-4109
ll	-2538	-2124	-2316	-2289	-3175	-4093
r2_a	0.0361	0.0572	0.0445	0.139	0.0590	0.0410
rss	275729	62983	125157	113460	2.654e+06	7.310e+07
mss	14981	4908	7966	20495	212354	4.368e+06
rmse	22.35	10.68	15.06	14.34	69.34	364.5
r2	0.0515	0.0723	0.0598	0.153	0.0741	0.0564
F	10.81	3.382	6.063	11.67	5.323	4.805
df_r	20	20	20	20	20	20
df_m	9	9	9	9	9	9
N_clust	21	21	21	21	21	21
Robust standard errors in parentheses						
*** p<0.01, ** p<0.05, * p<0.1						
Rates reflect the number of acute hospital stays from 2009-2013 per thousand New Jersey residents (RPK) per age cohort						
CCD - County Civil Division						

Appendix P Quintile Measure Regression Results Table: Acute Injury in Female Age Cohorts Using the Neighborhood Concentrated Disadvantage Index to Measure Socioeconomic Deprivation

PREDICTORS OF FALL-RELATED ACUTE HOSPITAL STAYS AMONG FEMALE AGE COHORTS
MEASURING SED WITH NEIGHBORHOOD CONCENTRATED DISADVANTAGE (NCD) & QUINTILE MEASURES OF POPULATION

VARIABLES	RPK FEMALES	RPK FEMALES	RPK FEMALES	RPK FEMALES	RPK FEMALES	RPK FEMALES
CCD POPULATION 2010 <20 PERCENTILE	4.705**	3.099**	3.303**	9.155**	58.88**	240.9**
	(2.003)	(1.247)	(1.212)	(3.376)	(25.09)	(86.72)
CCD POPULATION 2010 21-40 PERCENTILE	1.371**	1.317***	0.646	4.539***	29.92***	138.0**
	(0.517)	(0.436)	(0.643)	(0.957)	(10.06)	(55.70)
CCD POPULATION 2010 61-80 PERCENTILE	-0.636	0.133	-0.700	-0.917	-0.528	-7.526
	(0.476)	(0.401)	(0.559)	(1.122)	(9.334)	(39.78)
CCD POPULATION 2010 >81 PERCENTILE	-0.787	-0.434	-1.731***	-4.572***	-19.13**	-65.51**
	(0.456)	(0.444)	(0.532)	(1.231)	(6.758)	(28.73)
CCD POPULATION DENSITY <20 PERCENTILE	-2.602**	-1.549*	-2.029**	-6.771***	-32.52**	-77.64
	(1.089)	(0.868)	(0.827)	(2.201)	(11.96)	(67.88)
CCD POPULATION DENSITY 21-40 PERCENTILE	0.657	-0.464	0.126	-0.0533	3.056	47.79
	(1.949)	(1.225)	(1.619)	(2.453)	(11.76)	(84.57)
CCD POPULATION DENSITY 61-80 PERCENTILE	0.245	-0.257	0.466	2.963	30.60	78.28*
	(0.680)	(0.714)	(0.685)	(2.608)	(19.56)	(38.95)
CCD POPULATION DENSITY >81 PERCENTILE	0.450	-0.251	-0.829	-0.827	13.06	67.09
	(0.998)	(0.763)	(0.978)	(1.947)	(13.36)	(78.56)
CCD NCD 2010	-0.0173	0.0289	0.259**	0.630***	0.981	-0.533
	(0.0690)	(0.0528)	(0.105)	(0.156)	(0.762)	(3.176)
Constant	3.632***	2.797***	4.490***	13.14***	57.43***	216.6***
	(0.853)	(0.670)	(0.739)	(1.837)	(10.18)	(38.20)
Observations	562	562	562	562	562	562
R-squared	0.053	0.051	0.073	0.120	0.076	0.053
rank	10	10	10	10	10	10
ll_0	-2049	-1779	-1922	-2368	-3445	-4269
ll	-2034	-1764	-1901	-2332	-3423	-4254
r2_a	0.0373	0.0356	0.0583	0.106	0.0606	0.0371
rss	45728	17523	28499	132318	6.415e+06	1.240e+08
mss	2546	942.2	2256	18043	524966	6.855e+06
rmse	9.102	5.634	7.185	15.48	107.8	473.0
r2	0.0527	0.0510	0.0734	0.120	0.0756	0.0526
F	5.786	4.738	12.75	9.334	7.856	4.114
df_r	20	20	20	20	20	20
df_m	9	9	9	9	9	9
N_clust	21	21	21	21	21	21

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Rates reflect the number of acute hospital stays from 2009-2013 per thousand New Jersey residents (RPK) per age cohort
CCD - County Civil Division

Appendix Q Quintile Measure Regression Results Table: Acute Injury in Female Age Cohorts Using the Townsend Index to Measure Socioeconomic Deprivation

PREDICTORS OF FALL-RELATED ACUTE HOSPITAL STAYS AMONG FEMALE AGE COHORTS MEASURING SED WITH THE TOWNSEND INDEX (TSI) & QUINTILE MEASURES OF POPULATION SIZE & DENSITY						
VARIABLES	RPK FEMALES	RPK FEMALES	RPK FEMALES	RPK FEMALES	RPK FEMALES	RPK FEMALES
CCD POPULATION 2010 <20 PERCENTILE	4.520**	3.041**	3.067**	9.098**	58.35**	233.8**
	(1.993)	(1.267)	(1.135)	(3.373)	(24.89)	(85.36)
CCD POPULATION 2010 21-40 PERCENTILE	1.259**	1.283***	0.510	4.519***	29.62***	133.7**
	(0.523)	(0.419)	(0.643)	(0.995)	(10.07)	(55.32)
CCD POPULATION 2010 61-80 PERCENTILE	-0.677	0.105	-0.879	-1.217	-1.113	-9.174
	(0.441)	(0.398)	(0.552)	(1.233)	(9.607)	(38.87)
CCD POPULATION 2010 ≥81 PERCENTILE	-1.011**	-0.478	-1.805***	-4.166***	-18.99**	-73.97**
	(0.412)	(0.432)	(0.614)	(1.318)	(6.776)	(30.63)
CCD POPULATION DENSITY <20 PERCENTILE	-2.406**	-1.420	-1.227	-5.460**	-29.93**	-69.88
	(1.045)	(0.847)	(0.839)	(2.265)	(12.20)	(67.44)
CCD POPULATION DENSITY 21-40 PERCENTILE	0.779	-0.401	0.488	0.453	4.166	52.58
	(1.841)	(1.189)	(1.636)	(2.418)	(11.68)	(85.26)
CCD POPULATION DENSITY 61-80 PERCENTILE	0.130	-0.256	0.617	3.601	31.36	73.99*
	(0.652)	(0.731)	(0.647)	(2.694)	(19.41)	(38.44)
CCD POPULATION DENSITY ≥81 PERCENTILE	-0.0146	-0.374	-1.239	-0.567	12.39	49.42
	(1.213)	(0.865)	(0.814)	(2.042)	(13.82)	(76.71)
CCD TSI 2010	0.167	0.105	0.643***	1.025***	2.058	6.588
	(0.230)	(0.124)	(0.163)	(0.274)	(1.548)	(7.133)
Constant	3.795***	2.817***	4.440***	12.60***	56.95***	222.8***
	(0.848)	(0.662)	(0.742)	(2.063)	(10.47)	(36.17)
Observations	562	562	562	562	562	562
R-squared	0.054	0.052	0.084	0.114	0.076	0.053
rank	10	10	10	10	10	10
ll_0	-2049	-1779	-1922	-2368	-3445	-4269
ll	-2033	-1764	-1897	-2334	-3423	-4254
r2_a	0.0384	0.0364	0.0691	0.100	0.0608	0.0378
rss	45675	17507	28172	133148	6.414e+06	1.230e+08
mss	2599	957.8	2584	17213	526300	6.940e+06
rmse	9.096	5.632	7.144	15.53	107.8	472.9
r2	0.0538	0.0519	0.0840	0.114	0.0758	0.0532
F	7.381	4.152	9.489	9.022	6.187	3.615
df_r	20	20	20	20	20	20
df_m	9	9	9	9	9	9
N_clust	21	21	21	21	21	21

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Rates reflect the number of acute hospital stays from 2009-2013 per thousand New Jersey residents (RPK) per age cohort
CCD - County Civil Division